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SOCIETY OF FORESTERS OF GREAT BRITAIN

THIS SOCIETY was formed at Aberdeen in 1925 and adopted its first Constitution at Oxford in 1926. This has been modified several times and the present Constitution became operative from 25th September 1958.

The object of the Society is to advance and spread in Great Britain the knowledge of technical forestry in all its aspects. It is intended that the Society should be representative of the profession. Those not engaged in the practice of forestry or the allied sciences are cordially invited to join as Ordinary Members.

The activities include the publication of the journal, the holding of meetings, conferences, and excursions, and the awarding of a medal.

THE SOCIETY'S JOURNAL, called *Forestry*, is published twice a year, in May and November. It provides a means for the publication of the results of practice and research both in the growing of timber and in its utilization, including such basic sciences as forest physiology and ecology, forest soils, wood structure, and timber physics, and allied sciences such as forest entomology and forest mycology.

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[*continued on inside back cover*

Photograph: Nicholas Horne Ltd., Totnes

Entrance to the Main Courtyard of Dartington Hall, started 1385 by John Holland, Duke of Exeter. Behind *Taxodium* in foreground Bell Tower and Banqueting Hall. The Manor was a gift from the Duke's half-brother, King Richard II

PLATE I

THE SOCIETY IN SOUTH DEVON

IN 1958 the Society visited Dartington and the neighbouring forests at the invitation of the Dartington Hall Trustees and the Forestry Commissioners. The previous visit to Dartington had been in 1946 and an account of this will be found in volume xx of *Forestry* at pages 81 to 85. Record numbers attended both meetings. Over forty in 1946. Over a hundred in 1958. The 1958 meeting included visits to Park Woods, Kingswood, and Clifford Woods belonging to the Dartington Hall Trustees and to the Forestry Commission forests of Haldon and Fernworthy. The Society met from the 22nd to the 26th of September and the 31st annual general meeting and the evening discussion were both held at Dartington Hall. A brief appreciation of the visits to the woodlands and of the evening discussion on extraction is given below.

Among much shown and discussed in the Dartington woodlands, we may mention the problem of check in Douglas fir as the canopy closes; the most profitable market for Douglas; the growing of high-quality sports ash shown by Mr. Elmhirst; the stands of redwood and of hemlock and the management of Japanese larch which is considered more fully below. Measurement figures for Douglas, ash, redwood, hemlock, and larch are given in Table I by permission of the Trustees.

Mr. Hiley has written extensively about management for fast growth and we were looking forward to seeing some of his ideas demonstrated in the field. We were not disappointed. The example chosen was the management of Japanese larch following oak on favourable sites in this mild climate. The demonstration was an eye-opener for many of us. Kingswood near Buckfastleigh and Clifford Woods farther north near Moretonhampstead carried mainly poor oak coppice under conversion to conifers. Conversion was speeded up while the war-time demand for charcoal and tan bark lasted until there are now some 400 acres of Japanese larch between the ages of 10 and 25 years. Though it may one day be overtaken by Douglas fir, Japanese larch is at present Dartington's most profitable species. It is well suited to its environment. The average quality is class I and there is a ready market for thinnings up to 6 to 8 inches quarter girth at breast height. All these factors together with the need for early returns and the need to keep this larch growing rapidly have combined to encourage bold methods. These methods aim to market the greater part of the crop at 25 years. They were presented to us in a series of sample plots showing the crops from 12 years of age onwards. Measurements for some of these will be found in Table I and we may discuss a few examples. We were asked, for instance, to compare the development of the crowns of the final crop trees in plots 9 and 10 in Kingswood Compartment XO. Plot 9 had been thinned twice approximately in accordance with the Dartington numerical grade for Japanese larch. This means reduction to 500 stems per acre at 11 years and to 328 at 15 years. Plot 10 on the other hand had been thinned to a grade nearer the Forestry Commission yield table according to top height, that is to 700 stems per acre at 11 years and 440 at 15 years. The

TABLE I. *Record of measurements in Dartington sample plots.*

Age of plantation at S.P. measurement	*Species and plot no.*	*100 largest trees per acre**		*Main crop*			
		Mean ht. in ft.	*Mean b.b.q.g.*	*No. of stems*	*Mean b.b.q.g.*	*Basal area in b. sq. ft.*	*Volume in b. ft. o.b.*
Chasegrove. Compartment VIIIB. Ash P. 1914							
40	Ash	80	..	52	9·6	33·4	1,200
	Sycamore	60	..	28	8·0	12·6	312
North Wood. Compartment IR. Douglas P. 1900. Qu. cl. I							
57	Douglas	116	..	64	16·8	125·0	5,515
North Wood. Compartment IW. Redwood P. 1934							
23	Redwood	67	11·2	199	10·0	138·0	4,092
North Wood. Compartment IL. Western hemlock P. 1933							
23	Hemlock	63	8·1	348	7·1	121·2	3,549
Kingswood. Compartment XO. Plots 9 and 10. Japanese larch P. 1941. Qu. cl. I							
15	Jap. larch 9	43	5·9	328	5·3	64·0	1,236
15	Jap. larch 10	43	5·7	440	4·9	73·3	1,464
Kingswood. Compartment XT. Japanese larch P. 1943. Qu. cl. I							
15	Jap. larch	43	5·5	440	4·7	67·7	1,192
Kingswood. Compartment VIIK. Japanese larch P. 1936. Qu. cl. I							
22	Jap. larch	52	6·4	204	5·9	49·8	1,250
Kingswood. Compartment IA. Japanese larch P. 1932. Qu. cl. I							
25, 26	Jap. larch	57	7·0	144	6·7	45·0	1,260
Clifford. Compartment XVIC. Japanese larch P. 1930. Qu. cl. I							
25	Jap. larch	56	..	50	7·1	17·8	474

* If the number of trees per acre is less

In all appropriate cases figures refer to one acre

Last thinning			*Current annual increment*		
No. of stems thinned	*Mean b.b.q.g.*	*Volume in b. ft. o.b.*	*Basal area in b. sq. ft.*	*Volume in b. ft. o.b.*	*Remarks*
28	8·8	472	2·4	117	Gold medal Royal Show 1952. See also *Forestry* xx.
..	..	..	..	..	
32	14·5	2,026	4·0	261	Total yield since 1943 8,797 h. ft. o.b. See also *Forestry* xx.
96	8·1	1,360	14·3	478	Fastest conifer plot in Europe. Total yield 8,522 h. ft. o.b.
84	5·9	584	10·9	380	Total yield 6,042 h. ft. o.b.
172	4·8	512	7·9	242	See text. Planted 6 ft. by 6 ft.
264	4·0	528	8·7	262	See text. Planted 6 ft. by 6 ft.
212	4·2	425	..	..	Planted 8 ft. by 8 ft. Thinned 1957.
164	5·5	842	5·2	179	Thinned 1948, 1949, 1953, 1956. Approximates to Dartington thinning grade.
152	5·7	846	2·6	118	Thinned 1950, 1952, 1956.
..	..	..	..	..	See text. Growth 1955 to 1957 6 rings per inch b.h.

than 100 then mean height of main crop is shown.

Dartington grade is designed to develop and keep a large live crown and so enable the desirable width of the annual rings to be maintained. The mean tree in plot 9 was 3·77 hoppus feet after thinning compared with 3·33 hoppus feet in plot 10. An example of planting at 8 by 8 feet was shown in Kingswood Compartment XT. The next step, shown in the two examples which follow in Table I, is to thin *to* the final crop trees repeatedly to help them. Lastly we saw Clifford Compartment XVIC already reduced to 50 stems per acre and underplanted with tsuga, thuya, and Douglas fir. Had this crop been clear-felled at 25 years the money yield would have been 6·1 per cent. and 25 years may indeed be the financial rotation. The decision to leave 50 stems for a further 25 years was taken partly because of the national policy of conserving stocks which has only recently been modified and partly because it may be more profitable to do so. The argument for this is given by Mr. Hiley in his 'Underplanting of Japanese larch' printed in the *Quarterly Journal of Forestry* for July 1956, to which reference is invited. In this paper Mr. Hiley visualizes two-storied high forest with the undercrop heavily thinned and itself underplanted when the larch overwood is finally felled.

The country is it seems no longer bound by the need to build up stocks and the general case for growing trees fast and selling them early in the best markets is thereby strengthened. The bearing which the above demonstration has on the general case is plain, as is the compromise of two-storied forest (or pulpwood with standards as some call it) and the contribution which it makes towards securing a normal forest. But apart from this we may consider how far this sort of management for Japanese larch can be used elsewhere. There are other parts of southern England where growth is comparable and where there are fair markets for round thinnings but only poor ones for small saw logs. In such places the method should be most attractive particularly on private estates. It secures quick suppression of scrub or hazel. It provides early returns including stakes and rails. It permits a change of species within one generation, e.g. to pulpwood if advisable. And it produces no unwanted low-grade saw timber. For underplanting there is a wide choice of species which might even include larch again or sweet chestnut for coppice.

Up-to-date notes on the Forestry Commission forests of Haldon and Fernworthy are included in Rouse and Edlin's paper 'The Forests of South-West England' published in 1958 in *Forestry* xxxi at pages 27 to 51 and reference is invited to this paper for further information. The notes below cover the principal points seen during the excursion.

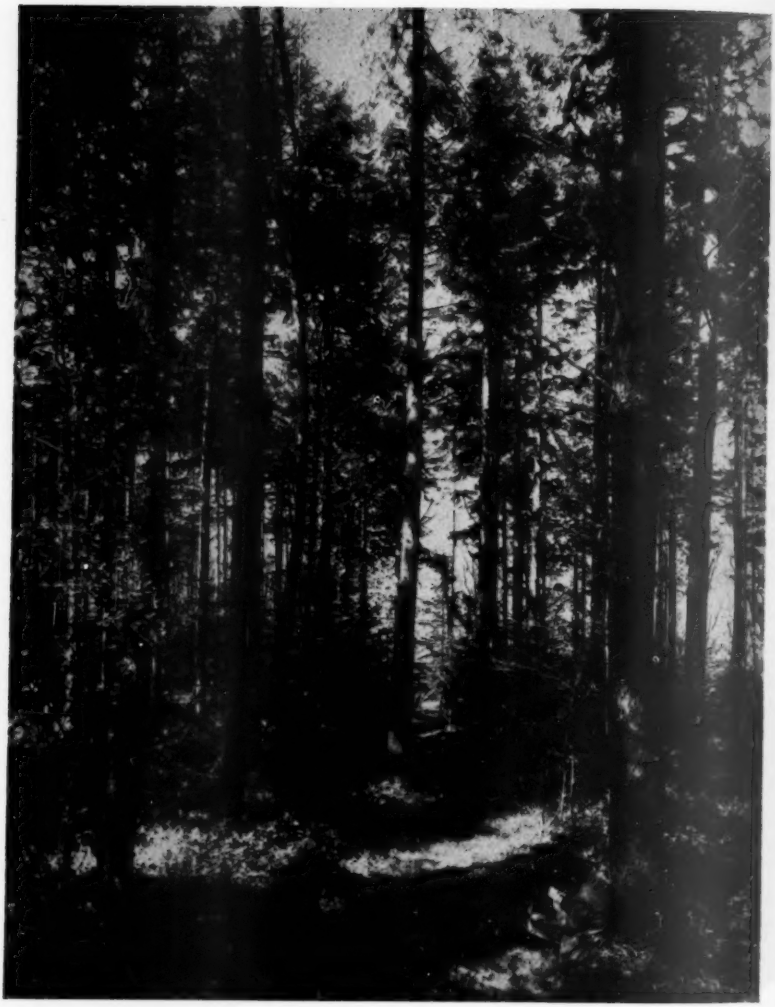
Haldon Forest lying close to two main roads from Exeter to the south-west and close also to a popular racecourse is a very high fire risk. Recent progress in road construction for the extraction of thinnings and the development of roadside fire traces together with the use of radio for reporting fires has reduced this risk. A new steel fire tower has been erected this year and the forest is now equipped with a mobile transmitter in a Land Rover and with four pack sets. The development of this system is being watched with interest with a view to its possible application in other areas.

The Haldon Plateau consists of extensive beds of flint and chert gravels with

Photograph: W. E. Hiley

Japanese larch, planted 1930. Clifford Compartment *XVI C.* Reduced to 50 stems per acre at 25 years. April 1956. Reproduced by courtesy of the Editor, *Quarterly Journal of Forestry*. See Table.

PLATE II



Photograph: Nicholas Horne Ltd., Totnes

Douglas fir, aged 40–50 years. Compartment *V D*, North Wood, Dartington: the pruning is natural.

PLATE III

Photograph: C. E. Hewetson

Douglas fir, planted 1900. Compartment *I R*, North Wood, Dartington: several trees exceed 120 feet in height and 100 h. ft in volume and are continuing to put on 7 rings per inch. September 1958. See Table.

PLATE IV

Photograph: C. E. Hewetson

Redwood, planted 1934. Compartment *I W*, North Wood, Dartington. Taller trees are over 75 feet in height. September 1958. See Table.

PLATE V

sand that is so compacted that drainage is impeded. Much of the earlier Scots pine dating from 1921 was planted without any cultivation and, although with the heavier machinery now available and with the use of phosphates the outlook is better for future planting, it has to be considered whether it is reasonable to persevere with these 600 acres or so of Scots pine, much of which remains obstinately in check. Following a survey in 1955, a comprehensive set of research plots has been laid down. These include various types of ploughing and manuring at the time of planting and there is also an experiment, one of three recently laid down in southern England, to study the nature of growth responses by low-quality pole stage crops to the application of nutrients. Discussion at Haldon was concerned largely with fire protection methods, with policy as regards the planting of poor sites in the light of recent modifications in planting policy generally, and with the planning of research programmes.

At Fernworthy, with a rainfall of 60 to 75 inches and high humidity, a main object of the visit was to demonstrate the superiority of Sitka spruce over Norway spruce in exposed positions at high elevation. There are now nearly 500 acres of Norway spruce and nearly 800 acres of Sitka spruce mostly in the thinning stage. The marketing of this material would have to be considered before long and one solution might be to establish a mill of the Ari type to deal with Haldon, Dartington, Fernworthy, and other nearby estates as has been done at Strachur in Argyllshire.

Problems of marketing were frequently raised and before concluding the account of the excursion we may mention a suggestion made by Mr. Elmhirst that research into marketing should be undertaken at one of the universities. This suggestion may well be heard of again.

For the evening discussion the subject chosen was extraction in its various aspects. Synopses of the main papers read were supplied to members before the meeting and a very brief account is given below.

The opening speaker, Mr. Ryle, regarded timber extraction as a factor in forest management. The responsibility for planning extraction rested on the forest officer and could not be divorced from the rest of forest management, but mechanical and highway engineering had outrun education in forest engineering and until we caught up he would need a professional engineer as his agent. There should be two stages only in extraction. Stump to road and road to consumer. For the first stage there was much to be said for the horse. The economics of extraction demanded substantial volumes per acre and thinnings and selection fellings must be boldly designed to provide them. Silviculture should be the handmaiden of economic forest management and not its extravagant mistress.

Mr. Huggard who followed said that roads were the basis of economic timber extraction. That was why some timber went to market while some stayed at home. Eight miles of road per square mile of forest was an acceptable average for density but local conditions of yield and costs affected the ideal density. More approach roads should be built even to small blocks. The price differences between timber growing at roadside and that farther away were too great and could be reduced economically by proper planning and good organization and management.

In some forests it seemed that road planning was only about 50 yards ahead of the bulldozer. Ideas were too varied and he advocated a code of practice for use by those in charge in the field.

Colonel Shaw said that mechanical aids were needed if extraction costs were to be reduced though he agreed that the horse still had its part to play. Power saws would soon be used everywhere. Their adoption in State forests had been slowed down only because of the predominance of thinnings, as tests showed that 9 inches diameter at butt was their economic minimum. He discussed four-wheel-drive tractors, the role of the truly portable power winch for log assembly, the development of the power-propelled sulky, cable-ways, recent mono-rail experiments, and, looking rather further ahead, the use of helicopters still too costly at 6*s*. per cubic foot lifted.

Mr. Grayson dealt briefly with some aspects of the economic assessment of road programmes and the next three speakers with certain practical details of extraction. Mr. Maxwell Macdonald discussed methods of selling thinnings and contracting for their extraction from private forests in Scotland. Mr. Rowan gave details of road progress in the Border forests and Mr. Rowland discussed the use ofthe Weasel-Diezel for extracting thinnings at Woburn. A general discussion then followed.

Two points in the discussion call for comment. Firstly the criticism that the training given to students in forest engineering is insufficient and out of date. Surely such training must be limited to basic principles and the fault lies rather in insufficient post-graduate and refresher courses? Secondly the agreement, which is confirmed by the work studies carried out over the past 2 years by the Forestry Commission (Mr. Zehetmayr), that the horse is still best for moving thinnings from stump to road side. Members were anxious that, with such large numbers of thinnings to be moved in the next few years, there should be sufficient horses or ponies of the right sort to move them. *There will not be unless something is done about it.* Nor, when we consider the drift away from horses that has taken place in British agriculture since the war, will there be the men to look after them. The alternative seems to be the 'truly portable power winch' and we must now make our choice.

Space is short and the above does but meagre justice to a meeting which showed over a hundred foresters the results of some of the best thinking and planning in British forestry today. We thank all responsible. Need any more be said? Perhaps that Dartington is unique and that it was great good fortune to have with us the two chief designers of their woods, Mr. Elmhirst and Mr. Hiley. We appreciate too Mr. Connell's decision to show us both failure and success in State forests, a decision which greatly enhanced interest. Many who come to Dartington will want to know more about the great social experiment being made there by Mr. and Mrs. Elmhirst. They may be referred to a book[1] which has recently been published and to the review of it in the *Quarterly Journal of Forestry* for October 1958.

[1] *Dartington Hall. The History of an Experiment.* By Victor Bonham-Carter with an account of the School by William Burnlee Curry. Pp. 224, 24 plates, 2 maps. Phoenix House Limited, London, 1958. Price 30*s*.

CONIFEROUS LITTER AMENDMENTS AND THE GROWTH OF SITKA SPRUCE

By L. LEYTON and J. WEATHERELL

SUMMARY

The growth of semi-checked Sitka spruce (*Picea sitchensis* Carr.) on heathland has been stimulated to different degrees by the annual application of litter of Scots pine (*Pinus sylvestris* L.), Corsican pine (*P. nigra* var. *calabrica* Schneid), Lodgepole pine (*P. contorta* Dougl.), Japanese larch (*Larix leptolepis* Gord.), and Sitka spruce, at rates corresponding to normal plantation conditions, following an initial heavier rate. Foliar analysis suggests that the response is at least partially attributable to the influence of the litters on the nitrogen nutrition of the spruce and differences between litters appear to be largely determined by their total nitrogen contents. In this respect, Japanese larch, with an annual needle fall generally greater than that of the pines and a higher nitrogen content, offers the best promise as a nurse species for spruce.

INTRODUCTION

THE afforestation of upland heaths has called for considerable research during the past 30 years or so. Most of the early natural surface plantings either produced slow-growing crops or failed entirely according to the particular species employed; pines, for example, generally gave rise to a slow-growing crop, larches often failed, whilst Sitka spruce, a popular species because of its potentially high yield and resistance to exposure, frequently went into severe check. Later measures such as ploughing and the application of phosphatic fertilizers considerably increased the chances of success, leading to better growth of the pines and to the successful establishment of Japanese larch, but did not preclude the onset of check in Sitka spruce and other species such as Norway spruce and Lawson cypress (*Picea abies* Karst. and *Chamaecyparis lawsoniana* Parl.).

Apart from the inherently low fertility of most heathland soils, various experiments have since disclosed the adverse effect on tree growth of the living heather vegetation itself; stimulation to the growth of checked spruce has been obtained by removing the heather by screefing or by suppressing it through mulching (Weatherell, 1953) or shade. From investigations into the nutritional relationships of the trees under these various treatments (Leyton, 1954, 1955, 1955), there would appear to be little doubt that checked growth can be at least partially attributed to severe nitrogen deficiency aggravated by the presence of the heath vegetation and that the beneficial influence of these treatments is due in part to their stimulation of nitrogen uptake by the trees. However, apart from the elimination of competition, the suppression of the heather by mulching or tree shade also provides a layer of vegetable material on the surface of the soil which, according to observation, considerably stimulates the growth of tree roots below it thus providing a further stimulus to growth.

Recognition of these effects has provided at least a partial explanation for the

beneficial influence of a nurse species on the growth of spruce in heather and to a certain extent, therefore, the merits of a particular nurse will depend on the rapidity with which it forms canopy and suppresses the heather by shade. This, however, may not be the only factor concerned; it has been suggested from observations and measurement (Weatherell, 1953) that Sitka spruce responds to the proximity of certain species, notably Scots and Corsican pines, even before the heath vegetation is suppressed and it may be, therefore, that the litter of the nurse species itself is able to exercise a beneficial influence on growth either through nutritional factors or otherwise. An experiment along these lines on a peat soil (Zehetmayr, 1954, p. 81) has suggested a slight response in spruce growth to the application of coniferous litter but no comparable investigations have been made in heathland plantations despite the obvious need for information under these conditions. The following experiment was therefore designed to determine whether in the first place poorly growing spruce in moderately vigorous heather can indeed be brought out of check by the application of tree litters alone and if so whether this can be interpreted in terms of nutritional or other effects: the occurrence of differential effects may then provide some basis for the selection of the most effective nurse species.

EXPERIMENTAL

Litter from plantations of five species, Japanese larch, Scots pine, Corsican pine, Lodgepole pine, and Sitka spruce, growing on heathland sites comparable with the one under investigation, was applied in May 1955 to a depth of 2 inches (approximately 7,260 cu. ft. per acre) in a young (14 years old) poorly growing plantation of Sitka spruce on Hackness (Broxa) Moor, Yorkshire; the initial preparation of the site consisted of single-furrow ploughing with subsoiling followed by a phosphate dressing. Further litter applications were made annually at a rate approximating to the annual needle fall in fully stocked stands of these species, approximately 900 cu. ft. per acre. The experimental layout was designed on a randomized block basis, each treatment (including control) being replicated five times to give a total of 30 plots each containing $4 \times 4 = 16$ trees and separated from each other by narrow trenches 8 inches deep. Because of the quantities of litter involved, collections usually had to be made from more than one stand of the species concerned, with the result that certain plots received litter of different origin and of somewhat different composition than others but, as will be seen, this does not invalidate the final interpretation of the results.

For the present investigation, two trees were selected at random from each plot, their growth recorded, and shoots from the uppermost whorl of laterals removed each autumn for subsequent needle analysis.

RESULTS

Table I gives data on the initial litter applications, their content of nitrogen and phosphate (in terms of per cent. dry weight), and bulk densities, according to origin.

Table II gives, for each treatment (independent of differences in origin), the

mean values for initial height, annual leader growth from 1954 to 1957, and the composition of the current needles (%N, %P) at the end of the 1955 and 1956 growing seasons. Where statistical analysis has revealed a significant treatment effect, the corresponding least significant difference at the 5 per cent. level of significance has been included.

TABLE I. *Composition and bulk densities of litters of different origin applied in 1955*

Species	*% d. wt.*		*Bulk density (lb./cu. ft.)*
	N	*P*	
Scots pine (1) . .	1·40	0·081	5·1
(2) . .	1·42	0·107	3·3
Corsican pine (1) . .	0·85	0·056	2·1
(2) . .	0·83	0·057	2·8
(3) . .	1·00	0·054	2·9
Lodgepole pine . .	1·07	0·097	3·9
Japanese larch . .	1·70	0·103	5·1
Sitka spruce (1) . .	1·37	0·109	7·0
(2) . .	1·47	0·079	10·6

TABLE II. *Growth and nutrient status of Sitka spruce, 1954–7*

Litter	*Ht. (cm.)*	*Ht. increment (cm.)*				*Needle composition*			
						N % d. wt.		*P % d. wt.*	
	1954	*1954*	*1955*	*1956*	*1957*	*1955*	*1956*	*1955*	*1956*
Control	130	9·5	9·0	7·5	6·3	0·79	0·83	0·101	0·089
Scots pine . . .	88	6·6	5·5	14·4	10·9	1·24	1·36	0·116	0·112
Corsican pine . . .	111	8·8	7·0	12·4	10·4	0·91	1·04	0·104	0·093
Lodgepole pine . . .	92	9·2	7·0	14·6	12·3	0·96	1·18	0·116	0·116
Japanese larch . . .	116	8·4	7·5	14·4	13·4	0·95	1·18	0·109	0·125
Sitka spruce . . .	92	6·5	7·1	17·7	16·7	1·41	1·43	0·147	0·131
Least significant difference (5%) . .				5·8	5·8	0·25	0·19	0·029	0·028

INTERPRETATION AND DISCUSSION

By the end of the 1955 growing season, no significant effect of any of the treatments on leader growth could be established, but the Scots pine and Sitka spruce litters, in particular, had led to a marked increase in the nitrogen concentration in the needles over that in the controls; with Sitka spruce litter there was also a significant increase in the phosphate status of the needles. By the end of the 1956 growing season all treatments (with the possible exception of the Corsican pine litter) had resulted in increased growth over the controls, together with increased nitrogen contents of the foliage: in two cases at least (Japanese larch and Sitka spruce litters), there was also a significant improvement in the phosphate status of the foliage. Although height increment in 1957 was generally below that

in 1956, the increased growth brought about by the litter treatments was maintained and, with the exception of Japanese larch litter, in much the same relative order as observed in the previous year.

In spruce it is well known that because the current shoots are completely determined in the terminal buds laid down in the previous year, responses in height growth to a particular treatment are first to be observed only in the following year; nutritional changes on the other hand may be observed in the same year of treatment. The correspondence to be observed in the results (Table II) between a higher nutrient content in one year and greater terminal growth in the following year would therefore suggest that the stimulating effect of the litter treatments may be interpreted in terms of their influence on the nutrition of the trees.

In order to test this statistically, the regression of height growth in 1956 on the nitrogen and phosphate foliage contents in 1955 has been calculated; after eliminating random sampling variations (block differences) and effects due to treatment (for details of this approach cf. Leyton, 1957), a highly significant linear correlation has been established ($r = 0{\cdot}563$, $p < 0{\cdot}01$) between height growth in 1956 and the nitrogen concentration in the 1955 needles. No evidence of a curvilinear component of the relationship was obtained nor was there any indication of a relationship with the phosphate content of the needles. These findings indicate, therefore, that some 30 per cent. of the variation in height increment in 1956 can be attributed to changes in the nitrogen content of the needles in 1955 and since such changes were induced by the application of certain tree litters (particularly of Scots pine and of Sitka spruce), the litter effect can be attributed in part at least to their stimulating effect on nitrogen uptake by the spruce. A similar analysis of the following year's data again yielded a linear relation between height increment in 1957 and needle nitrogen concentration in 1956.

These findings fully confirm the results of previous investigations into the growth and nutrition of Sitka spruce on heathland in that growth limitations can be attributed at least partially to nitrogen deficiency and that the ameliorative effect of different treatments is at least partially explained by their making more nitrogen available to the tree (this being reflected, over a certain range, in a higher nitrogen concentration in the needles). The extra nitrogen may originate directly from that contained in the litters and/or indirectly through some influence of the litter on nitrogen mobilization in the soil; promotion of a more vigorous rooting system must also be taken into account since in earlier trials of this kind a marked rooting activity of the spruce in the litter layer has been observed.

It is evident from the actual litter composition (Table I) that the response in growth is not entirely proportional to the percentage nitrogen content of the various litters: whilst the Corsican pine litter with the lowest content of this nutrient has given the smallest response, Japanese larch litter with the highest nitrogen content has not given the greatest response. This apparent anomaly, however, is largely explained when allowance is made for the varying bulk densities of these litters (Table I). Assuming that the same volume of litter has

been applied to each plot (2-inch depth), then the weight of litter will be dependent on its bulk density and it is readily seen that even when allowance is made for differences in nitrogen composition, much more nitrogen has been added in the spruce litter (with a very high density) than in the larch litter with a much lower density.

In the absence of specific data on litter moisture contents and mineral composition over the period of the investigation, the actual amounts of nitrogen added in each treatment cannot be determined with any certainty, but the order of magnitude of the quantities concerned may be estimated on the assumption that the dry matter content of the litters is approximately two-thirds of the fresh weight and that the nitrogen content remains approximately constant over the

TABLE III. *Approximate amounts of nitrogen added in litter treatments (lb./acre)*

Year	*Scots pine*	*Corsican pine*	*Lodgepole pine*	*Japanese larch*	*Sitka spruce*
1955 . .	284	111	200	415	599
1956 . .	35	14	25	51	74
1957 . .	35	14	25	51	74
Total . .	354	139	250	517	747

period. These estimates are given in Table III; whilst the initial application in 1955 was of course very much heavier than would be expected annually from the stands concerned, the subsequent applications and the quantities of nitrogen involved are of the same order as found in previous investigations (e.g. Bonnevie-Svendsen and Gjems, 1957; Wright, 1957).

In Fig. 1, for each treatment, the mean total height increment of the trees over the period 1955–7 (inclusive) has been plotted against the estimated amounts of nitrogen added during this period in the litters; the clear indication that response is more or less proportional to the amount of nitrogen added in the litter would suggest, therefore, that the merits of any particular litter are to be determined largely by its total nitrogen content.

The amount and composition of the annual litter fall under normal plantation conditions will, of course, vary appreciably, not only with species but also with age, stand density, and site conditions. From the few comparative investigations which have been made on the above species (e.g. Bonnevie-Svendsen and Gjems, 1957) there is some evidence that, other factors being equal, spruce and larch produce heavier litter falls than the pines; at the same time there is also some evidence that on similar sites larch litter generally possesses a higher nitrogen content than either spruce or pine litter (Table I, also Ovington, 1956). Naturally other factors have to be taken into account such as the decomposability of the litters and their provision of a suitable substrate for root development: according to Bonnevie-Svendsen and Gjems (1957) humus conditions under larch appear to be more favourable than those under spruce or pine. Taking

all these factors into consideration, therefore, Japanese larch would appear to have distinct advantages, at least over the pines, as a nurse for spruce.

The phosphate contributed by the litters does not appear in this case to be of particular importance in the growth response of the spruce; whilst there is some indication that the phosphate content of the spruce foliage is dependent on the amount of phosphate contained in the litters, the absence of any definite relationship between growth and phosphate status would suggest that the uptake of extra phosphate is to be associated with luxury consumption: this conclusion is

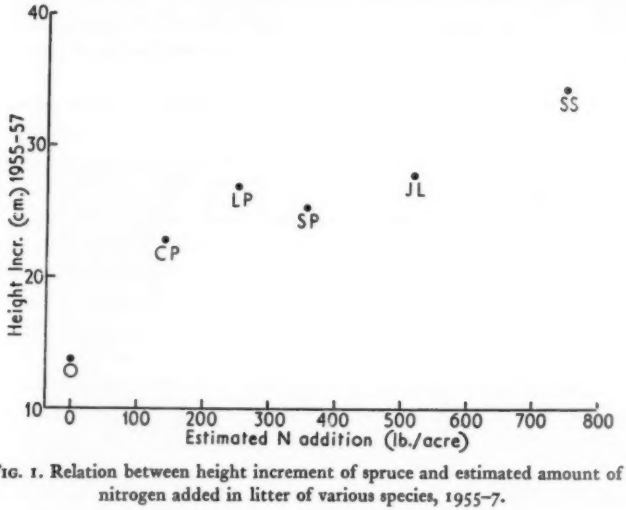


FIG. 1. Relation between height increment of spruce and estimated amount of nitrogen added in litter of various species, 1955–7.

supported by the observation that even in the untreated controls the phosphate content of the foliage is well above the level suggested as critical for spruce (about 0·06 per cent., cf. Tamm, 1956, p. 45).

CONCLUSIONS

There can be little doubt that even in the presence of vigorous heather the addition of a coniferous litter acts as a stimulant to the growth of spruce and, according to the above investigations, the effect must be attributed largely to the supply of extra nitrogen to the trees: no doubt the stimulation to rooting and the beneficial influence of the resulting mulch on moisture conservation also contribute to the growth response. The observation that the degree of the response is approximately proportional to the amount of nitrogen added in the litter would suggest that the most effective nurse species would be that which produces the greatest weight of litter with the highest nitrogen content, apart from its capacity to grow rapidly under heath conditions so as to suppress the heather in the shortest possible time. In these respects at least, Japanese larch is undoubtedly the most promising, having a nitrogen content which is generally

higher than that of the pines and producing a greater annual litter fall. Experience has already shown that once established this species is capable of growing quite vigorously in the presence of heather and in row mixture with spruce has very successfully brought the spruce into canopy (Weatherell, 1957).

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NIELS BROCK ULRICH

Mr. N. B. Ulrich, Director of State Forestry in Denmark, died suddenly in November 1958 at the early age of 51. Members will recall that he was made an Honorary Fellow of the Society of Foresters on the occasion of its visit to Denmark in 1955. Mr. Ulrich graduated in forestry in 1931, and entered the State Forest Service in 1935, becoming its Director in 1946. He was, in addition, Chairman of the Forest Research Commission and Vice-Chairman of the Danish Forestry Society, and a member of many other bodies concerned with forestry. He was a Knight of the Order of Dannebrog.

The Society was greatly indebted to him for his part in arranging the visit in 1955, and will recall the kindness and hospitality with which he received us. Mr. Ulrich was particularly interested in the development of forestry in Great Britain, and had expressed his intention of visiting this country shortly to attend an annual meeting and excursion of the Society. He was greatly appreciative of the Honorary Fellowship bestowed upon him. It is sad that this link with Danish forestry should be broken so soon. G. E. G.

THE CHEMICAL COMPOSITION OF PRECIPITATION IN ADJACENT FOREST AND OPEN PLOTS

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SUMMARY

The chemical composition of the precipitation in three open plots and under thirteen different forest canopies is compared for a 2-year period at an experimental forest in south-east England.

The average contents of sodium, potassium, calcium, and magnesium in the precipitation in the open are 19, 3, 11, and less than 4 Kg./Ha./annum respectively, compared with 33, 24, 24, and 10 under the forest canopies. Only very small quantities of phosphorus were present in the precipitation.

The data are discussed with particular reference to the nutrient cycles of forest stands, the removal of nutrients by logging, and the maintenance of soil fertility.

INTRODUCTION

As part of a general investigation into the effects of different tree species on soil conditions, the nutrient cycles in adjacent forest and treeless plots are being studied at Bedgebury in south-east England (Ovington, 1953, 1954*a*, 1955, 1956*a* and *b*, and in press). The assessment of the importance of precipitation in the nutrient cycles of the forest plantations is a fundamental part of these studies and consequently an attempt has been made to obtain qualitative and quantitative data of the chemical composition of the precipitation both under the forest canopies and in neighbouring treeless areas.

METHODS

Two rain gauges were placed at random in each of thirteen forest and three open plots, the open plots being widely separated over the experimental forest area. The rain gauges were made completely of polythene to prevent breakage in transport and because of the resistance of polythene to chemical attack (Egnér *et al.*, 1955). Each gauge consisted of a Buchner funnel 10 cm. in diameter which contained a No. 44 Whatman filter paper and was mounted in a collecting bottle of 40 oz. capacity. The rim of each funnel was approximately 30 cm. above the soil surface and little soil splashing into the funnels occurred. The filter papers prevented litter being washed into the collecting bottles and the papers were renewed as required to minimize pollution of the rainwater by litter, bird droppings, &c., caught in the gauge funnels. The collecting bottles were changed and the precipitation analysed at 5-week intervals over the 2-year period from 4th May 1955 to 8th May 1957.

On arrival at the laboratory each sample of rainwater was filtered through a Whatman No. 44 filter paper and the filtrate analysed. Duplicate determinations were made of sodium and potassium with an EEL flame photometer, and of

calcium by the versenate technique using ammonium purpurate (murexide) as an indicator. Single determinations were made of phosphorus by the molybdate blue method and magnesium by the titan yellow method, employing a Spekker absorptiometer. Occasionally the amounts of iron in the samples were determined using the dipyridyl method, but only negligible quantities were recorded.

During relatively dry months insufficient rainfall was collected to assess the concentrations of all the elements mentioned previously. However, the amounts of sodium, potassium, and calcium in the rainwater were always determined, and only the records for magnesium and phosphorus are incomplete. Frequently the concentrations of phosphorus and magnesium in the rainwater collected in the open were too small to be measured by the analytical techniques used, the minimum concentrations being less than 0·05 and 0·5 p.p.m. respectively.

TABLE I. *The chemical composition of the precipitation samples (p.p.m.)*

	Open plots		*Forest plots*	
	Minimum	*Maximum*	*Minimum*	*Maximum*
Sodium. . .	0·3	8·2	0·6	110·1
Potassium . .	0·05	3·5	0·2	42·8
Calcium . .	0·2	9·8	1·0	128·8
Magnesium . .	< 0·5	0·9	< 0·5	12·5
Phosphorus . .	< 0·05	0·5	< 0·05	1·0

RAINFALL IN THE OPEN

It is possible that the chemical composition of the rain collected in the open plots is not truly representative of the general rain falling on the experimental area as a whole, since the openings are only 30 m. by 30 m. square (Tamm, 1951). However, there did not seem to be any significant effect of the surrounding plantations since the chemical composition of the rainwater collected in the treeless plots is broadly similar to that reported for other localities of comparable geographical situation. Of all the elements that were determined, sodium, potassium, and calcium are by far the most abundant. A wide range of concentrations for individual elements has been recorded and the minimum and maximum concentrations of different chemical elements in the samples of precipitation, collected during the two years, are given in Table I. In general, the higher concentrations of the elements are associated with periods of low rainfall. This inverse relationship is significant at the 1 per cent. level for potassium and calcium (Fig. 1). In the case of sodium there is a marked seasonal effect with the highest concentrations of sodium occurring during winter, so that there is no significant relationship between the concentration of sodium and the amount of precipitation in the sampling period.

Daily records of precipitation are made at Bedgebury and the annual precipitations for the two sample years (792 and 871 mm.) approximate to the long period

average of 840 mm. (Forestry Commission, 1951). By combining the daily rainfall records with the analytical data it has been possible to determine the total weights of plant nutrients contained in the rainfall of each sampling period (Fig. 2). During the 6 months from March to August the weights of sodium per period are relatively constant, averaging about 0·5 Kg./Ha., but after August

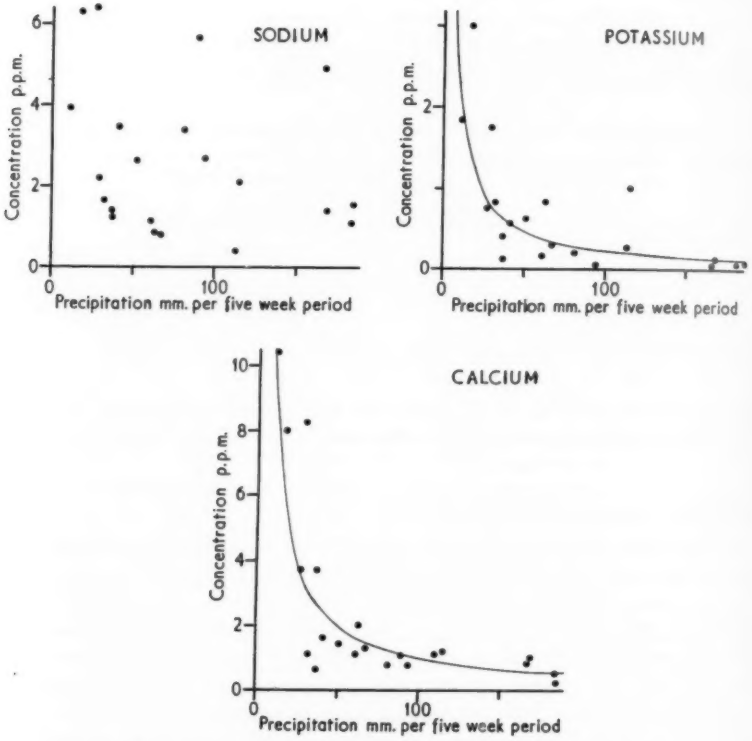

FIG. 1. The relationships between amounts of precipitation in the open and the concentrations of sodium, potassium, and calcium.

the weights increase to a maximum value of about 5·5 Kg./Ha. in January, before declining to the summer level. The winter months are characterized by heavy rainfall and the weight of sodium in the rain is positively correlated with the amount of precipitation occurring in the 5-week periods. The large sodium values recorded in July and August 1956 are unusual for the time of the year and are associated with a heavy rainfall, almost twice the average for these months over the 15 years 1934–48. Relatively large amounts of sodium, approx. 19 Kg./Ha./annum, are contained in the precipitation at Bedgebury (Table II), which is not surprising

since Bedgebury is only 27 km. from the coast (Emmanuelson *et al.*, 1954; Gorham, 1955).

Compared with sodium, considerable fluctuation occurs in the amounts of potassium or calcium contained in the rainfall of the open plots for different sampling periods. There is little evidence of any systematic seasonal variation or

TABLE II. *The sodium, potassium, calcium, and magnesium (as Kg./Ha./annum) contained in the precipitation of forest and open plots. The sample years begin on 4th May*

	Sodium			*Potassium*			*Calcium*			*Magnesium 23.5.56–4.4.57*
	1955–6	*1956–7*	*Average*	*1955–6*	*1956–7*	*Average*	*1955–6*	*1956–7*	*Average*	
Hardwood coppice	51·5	57·0	54·3	60·5	56·2	58·4	47·4	45·8	46·6	20·9
Nothofagus obliqua	27·4	32·8	30·2	21·4	14·8	18·1	23·8	22·7	23·3	9·2
Quercus petraea	18·5	19·2	18·9	24·4	19·9	22·2	15·7	13·5	14·6	7·7
Quercus rubra	19·8	22·2	21·0	13·3	11·3	12·3	13·1	14·0	13·6	6·1
Average for hardwood plantations	29·3	32·8	31·1	29·9	25·6	27·8	25·0	24·0	24·5	11·0
Picea omorika	35·1	46·8	41·0	33·6	44·3	39·0	29·6	33·5	31·6	13·3
Larix eurolepis	36·8	42·2	39·5	24·0	31·4	27·7	32·5	31·7	32·1	12·2
Abies grandis	36·3	52·9	44·6	14·1	22·9	18·5	27·7	34·4	31·1	9·5
Tsuga heterophylla	39·9	52·1	46·0	14·1	18·8	16·5	28·6	29·9	29·3	9·9
Pseudotsuga taxifolia	28·1	34·0	31·1	22·4	32·6	27·5	20·9	22·6	21·8	8·9
Picea abies	23·2	32·2	27·7	19·5	36·1	27·8	14·3	18·3	16·3	7·9
Pinus nigra	21·1	27·2	24·2	15·3	22·0	18·7	16·5	20·5	18·5	6·6
Chamaecyparis lawsoniana	23·4	28·3	25·9	13·7	14·0	13·9	15·9	18·5	17·2	5·8
Thuja plicata	24·7	24·7	24·7	18·4	8·7	13·6	19·5	18·8	19·2	5·3
Average for conifer plantations	29·8	37·8	33·8	19·5	25·6	22·6	22·8	25·4	24·1	8·8
Average for forest plantations	29·7	36·3	33·0	22·7	25·6	24·2	23·5	24·9	24·2	9·5
Average for open plots	18·8	19·6	19·3	2·5	3·1	2·8	11·8	9·5	10·7	<4·2

of any relationship between the amounts of these two elements and the total precipitation or number of rain days. If a very exceptional value of 1·15 Kg./Ha. is omitted, the average 5-weekly total for potassium is 0·23 Kg./Ha. (S.E. of mean 0·03) and the average for calcium is 1·0 Kg./Ha. (S.E. of mean 0·1). On a yearly basis, about 2·3 and 10 Kg./Ha. of potassium and calcium respectively are contained in the rain falling in the open plots.

RAINFALL IN THE FOREST PLOTS

The precipitation collected beneath the forest canopies normally contains greater percentages of plant nutrients than the precipitation of the open plots for the same sampling periods. For instance, the maximum values of nutrient content (as parts per million) in the rain samples collected during the 2 years are very much greater for the woodland samples than for those from the open areas (Table I).

Part of the precipitation falling on woodlands is intercepted by the tree crowns and a proportion of this evaporates directly back into the atmosphere without ever penetrating through the canopies. Consequently, smaller amounts of rainwater reach ground level in the forest plots than in treeless areas (Ovington, 1954*b*). Nevertheless, the precipitation beneath the forest canopies contains a

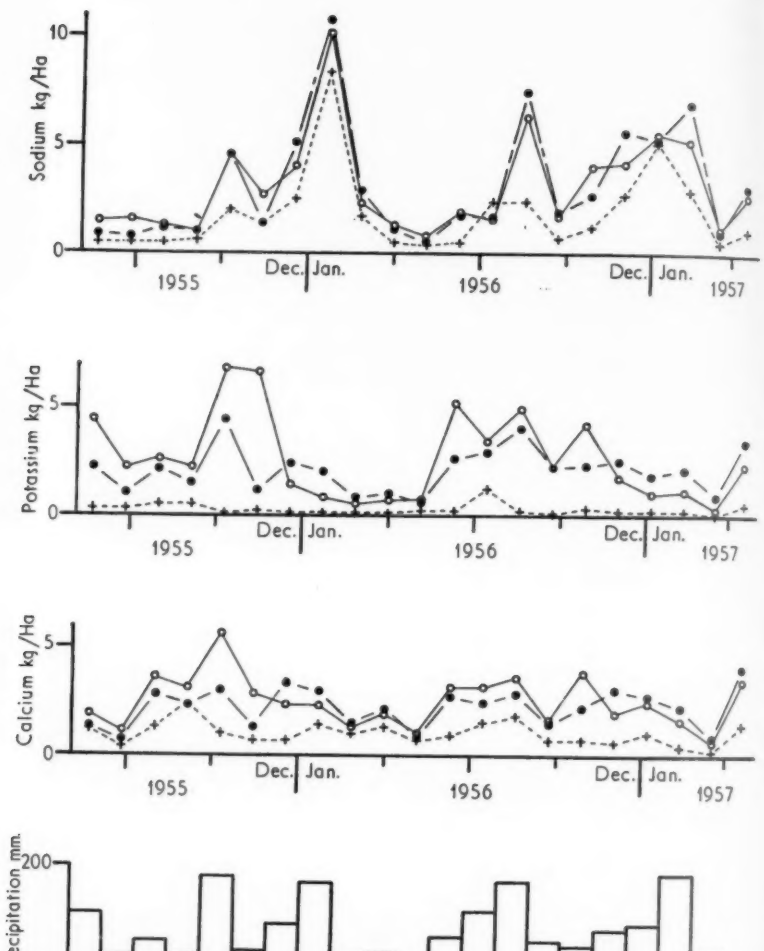

Fig. 2. The contents of sodium, potassium, and calcium in the precipitation in the open (+———+) under deciduous (○———○) and evergreen (●———●) tree canopies.

greater total weight of plant nutrients than that of the open plots, since the increase in concentration of nutrients more than compensates for the loss of water through interception. The nutrient content of the rainwater that flows down the tree stems was not determined, but this water would contain additional amounts of nutrients (Pozdnyakov, 1956) to those in the precipitation collected beneath the tree crowns.

The weights of the chemical elements contained in the rain, passing through the three canopies, vary throughout the year and tend to follow a seasonal cycle. The cycles are broadly similar for all tree species but differences occur between deciduous and non-deciduous species as groups (Fig. 2). During the leaf-bearing seasons greater amounts of nutrients are contained in the rainwater under stands of deciduous trees than of evergreens, but in winter, after leaf fall has occurred, the reverse is true. Although leaf fall is associated with a reduction in the amounts of sodium, potassium, and calcium contained in the rainwater of the deciduous plantations, it is interesting that the precipitation collected beneath the canopies of these plantations still contains more of the three elements than the precipitation of the treeless plots. The enrichment of the rainwater apparently results from interception by the tree branches as well as the leaves.

The amount of sodium in the rain collected under the tree canopies closely parallels the quantities in the open, the two annual cycles being very similar except that the results for the forest area are about 1 Kg./Ha./month above those for the open. The unusually high value of sodium recorded in August 1956 corresponds to the values expected for the winter maximum and it is interesting that extensive saltburn of the trees occurred in southern England at this time (Edlin, 1957). On an annual basis the amount of sodium in the rainfall under different tree species varied from 19 to 54 Kg./Ha.

The amount of potassium contained in the precipitation for the 5-week periods varies greatly during the summer, though in winter the results are more uniform. The average values for potassium under forest conditions for the autumn maximum and the spring minimum periods are about 3·5 and 1 Kg./Ha./sampling period respectively. Compared with the unplanted plots, there is a marked increase in the potassium content of the rain under forest canopies, the annual totals ranging from 12 to 58 Kg./Ha. depending on the tree species that has been planted. The average annual value for the woodlands is almost ten times that of the open.

The calcium results are also very variable though, as in the case of potassium, there is a tendency to an autumn maximum and spring minimum. The totals under the forest vary from 14 to 47 Kg./Ha./annum with an average just over twice that in the open.

The results for magnesium are incomplete, but it was possible to make one continuous set of measurements over the ten months from 23rd May 1956 to 4th April 1957. During this time the amount of magnesium in the rain under the trees varied between 5·3 and 20·9 Kg./Ha. Since the average magnesium values under the forest canopy were relatively constant from month to month, it seems likely that the total magnesium in the forest rain for the year would be about

6 to 24 Kg./Ha. As the concentrations of magnesium in the open were too small to be measured by the present method (less than 0·5 p.p.m.) it is impossible to obtain an exact figure for the excess of magnesium in the precipitation beneath the canopies, but it would vary from 2 to about 20 Kg./Ha./annum.

Of the 414 determinations of phosphorus in the rainfall under the tree crowns, over one-half contained less than 0·05 p.p.m. of phosphorus so that the total phosphorus content of the precipitation cannot be calculated.

DISCUSSION

Actively growing woodlands annually take up large amounts of plant nutrients from the soil and, since many of the localities available for afforestation in Britain

TABLE III. *The annual incorporation of plant nutrients in the tree crops (Kg./Ha.) compared with the nutrient content of the precipitation*

		Sodium	*Potassium*	*Calcium*	*Magnesium*	*Phosphorus*
	Age of trees	*Min. Max.*	*Min. Max.*	*Min. Max.*	*Min. Max.*	*Min. Max.*
Bedgebury tree boles and crowns .	21 yrs.	0·2–1·4	4–32	6–26	0·9–5·4	0·7–4·7
Bedgebury tree boles only . .	21 yrs.	<0·1–0·4	2–12	3–12	0·3–2·2	0·3–1·4
Abbotswood tree boles and crowns .	47 yrs.	0·1–0·3	2–6	4–15	0·9–2·5	0·3–2·1
Abbotswood tree boles only . .	47 yrs.	0·1–0·2	1–4	3–8	0·7–1·5	0·2–0·8
Bedgebury precipitation in the open .	..	19	3	11	<4	<0·4

have soils of low base status, concern has been expressed lest afforestation should result in soil impoverishment and, ultimately, in decreased productivity. However, a large proportion of the annual uptake of plant nutrients by trees is returned to the soil in the leaves and branches falling to the ground. When forests are harvested, only the tree boles are removed and the crowns are left to decompose on the forest floor so that some of the nutrients in the trees are returned to the soil. Nevertheless, after 20 years of growth the tree boles in forest plantations contain significant amounts of nutrients which, if they were obtained solely from the soil, would represent a serious drain by the trees on the soil reserves.

An extensive literature giving data of the chemical composition of rainwater already exists (Eriksson, 1952) and, although the precipitation from many localities in Britain has been collected and analysed, it has rarely been considered as an important source of nutrients available for tree growth. The results of the analysis of the precipitation in the open plots at Bedgebury supports the results of other investigators, who have shown that appreciable amounts of plant nutrients are contained in the annual precipitation. Comparisons of the nutrient content of the precipitation in the open plots and the build up of nutrients in the trees at Bedgebury and at an older series of plots at Abbotswood indicate that, except for phosphorus, the amounts of nutrients contained in the precipitation is broadly equivalent to or greater than the permanent annual incorporation of nutrients in the tree crops (Table III). The supply of nutrients may be increased further by the tree crowns catching aerosols (Eriksson, 1955) and dust (Tamm and Troedsson, 1955), which are washed off the branches and leaves during periods of rain. There have been few detailed studies of the loss of nutrients in the run-off from

wooded areas although Viro (1953) has made a general study of the nutrient balance for Finland as a whole. Some water must be lost from the soil by evaporation and transpiration so that run-off is considerably less than precipitation but the drainage water contains appreciable amounts of plant nutrients, although these may originate through leaching of the soil at certain depths.

The increase in the nutrient content of the precipitation after interception by the tree canopies at Bedgebury varies from plot to plot and may result from a variety of factors. The precipitation in some marginal plots, e.g. the shelterbelt coppice, *Pseudotsuga taxifolia*, and *Abies grandis*, contains relatively large amounts of the chemical elements and this may be due partly to the greater likelihood of dust being caught on tree canopies at the edge of the experimental area. Studies using radioactive isotopes have confirmed that certain chemicals can be absorbed by plants from solutions sprayed on their leaves (Thorne, 1955), but nutrients are also washed out of leaves by rain (Mes, 1954). In the forest plots months of heavy precipitation tend to have the greatest increase of nutrients in the rainwater. No close relationship exists between the composition of the tree leaves in the different plots and the increase in the amounts of plant nutrients contained in the rainfall. This is not surprising since many other factors beside leaf composition must affect the loss of elements from the tree canopies by leaching, e.g. the total weight of leaves and branches per plot, leaf shape and morphology, and the relative mobility of different ions. Mann and Walker (1925) found that 99·7 per cent. of the potassium could be leached from apple leaves of the Cox variety and 86·4 per cent. for the Bramley. In view of this, it is interesting that of all the elements that were determined in the precipitation, the greatest increase is for potassium.

ACKNOWLEDGEMENTS

It is a pleasure to acknowledge the co-operation of the Forestry Commission, on whose land the samples were collected, and of Mr. A. Westall, in particular, who dispatched the samples with unfailing regularity. The chemical analyses were made by Mr. H. M. Grimshaw and Miss J. D. Stable of the Nature Conservancy.

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R. C. FISHER

Dr. R. C. Fisher, B.Sc., Ph.D., F.R.S.E., had been in charge of the Section of Entomology at the Forest Products Research Laboratory since its inception in 1927. His death recently removes a very great authority on the timber insects and will be sorely felt. He was author or co-author of numerous papers on entomology and his advice was sought widely on all aspects of wood-boring insect infestations and their control. He was a member of long standing of this Society and a frequent contributor to this Journal in its early days, while recently he had encouraged the writing of more than one paper published in it. With B. J. Rendle, he compiled its first ten-year index. The gallantry with which he endured many years of increasing physical infirmity was an example to all who had the privilege to meet him and to his many friends. We offer our sympathy to his widow and sons.

ABNORMALLY HEAVY THINNINGS IN YOUNG LARCH

By M. V. EDWARDS

(*Forestry Commission*)

SUMMARY

A short assessment of an experiment with European larch (*Larix decidua* Miller) in four forests in Scotland. Starting in 1944 at a mean height of approximately 10 feet, the crops were reduced every alternate year to a stocking of 800, 600, 400, and 200 trees per acre, on the lines of South African work. A control was thinned to D grade. This preliminary assessment indicates that, with the comparatively slow rate of growth in Scotland, the optimum intensity of thinning is that which gives the maximum growing space commensurate with the control of competing vegetation and that the arbitary reductions in stocking in this experiment mostly exceeded this optimum.

Disease and die-back occurred in three of the experimental areas. The heavy thinnings reduced the number of cankered, dead, and dying trees, but did not cure the trouble on the more resistant remainder. Even under the heaviest thinning grade, a proportion of trees were cankered or died.

IN the early 1940's the prevalence of die-back and disease in European larch (*Larix decidua* Miller) in a number of forests was causing concern. Observations showed that the crops improved after thinning and sometimes recovered, suggesting that heavy thinnings might be beneficial to cure or prevent the trouble. Craib (1939) had recently published his bulletin advocating heavy thinnings in South African exotic conifer crops, and the opportunity was therefore taken to test some of his theories on larch in Scotland, both for normal management purposes and for the avoidance of die-back.

O'Connor (1935) had proposed thinning a set of plots to 800 trees per acre, then reducing all but one to 600, and later all of these plots but one to 400, and so on progressively down to 100 per acre. A similar procedure was followed in the Scottish experiments by W. H. Guillebaud and J. A. B. Macdonald.

THE CONDUCT OF THE EXPERIMENTS

In 1943–4 sites were selected in four young larch crops in different parts of Scotland.

Loch Ard Forest, Achray block, in Perthshire. A promising larch site, with bracken and pasture grass vegetation. Elevation 400 feet. Crop aged 8 years and 6 to 12 feet tall. Seed believed to be of Alpine provenance.

Clashindarroch Forest in Aberdeenshire. A marginal larch site on compact boulder till with dense heather vegetation. Elevation 1,000 feet. Crop aged 9 years and estimated at 6 to 9 feet tall. Seed of mixed provenance collected in north-eastern Scotland.

Glen Tress Forest in Peeblesshire. A promising larch site, with bracken, heather, and pasture grasses. Elevation 900 feet. Crop aged 10 years and almost closing canopy. No record of seed provenance: it later appeared to be alpine with a small proportion of Sudeten plants, possibly beat-ups.

Lael Forest in Wester Ross. A first-class larch site, with grass and bracken vegetation. Elevation 100 feet. Age 6 years and mean height about 10 feet. No record of seed provenance.

The plan provided for the immediate removal of nearly half the trees, leaving 800 to the acre, and the progressive removal (in all plots but one) every other year of a further 200 trees per acre, until only 200 per acre were left after 6 years in the most heavily thinned plots. A control for normal thinning (D grade) was also established, and in two of the experiments a further control for very light thinning was added. In each experiment the treatments were replicated three times in ⅛-acre plots with surrounds.

TABLE I. *First assessment. Mean heights of the largest 100 trees per acre (feet)*

Treatment and theoretical no. of trees per acre	*Loch Ard Aug. 1951 age 16 years*	*Clashindarroch June 1951 age 16 years*	*Glentress Sept. 1951 age 18 years*	*Lael Nov. 1954 age 17 years*
A (200)	20·9 [14]	17·2 [16]	26·3 [15]	35·8 [13]
B (400)	21·6 [13]	17·9 [14]	26·5 [?]	37·4 [13?]
C (600)	22·0 [10?]	17·5 [11]	26·7 [?]	37·4 [8]
D (800)	22·7 [8]	17·0 [9]	25·9 [10]	36·6 [6]
E (unthinned to date)	22·1	17·2	27·4	35·7
F (unthinned)	..	17·4	25·4	..
Mean	21·9	17·4	26·4	36·6
Standard error ±	0·66	0·66	0·79	0·96
Differences.	Not sigt.	Not sigt.	Not sigt.	Not sigt.

Figures in square brackets indicate the age at which the final reduction to the numbers required was carried out. All plots in A to D were reduced to 800 trees per acre at first thinning, A to C to 600 at second thinning, A and B to 400 at third thinning, and A only to 200 at fourth thinning.

The thinning treatments had been completed before the growing seasons of 1950 or 1951, by which time the top height of the trees in the different experiments varied between 17 and 26 feet (Table I). In the experiment at Lael Forest some of the operations fell into arrears, and corresponding measurements were not made until after 1954 when it had reached a mean height of 37 feet, at about the same age.

At this stage, the mean girths of the 100 largest trees per acre were as given in Table II, and did not show any significant differences.

RESULTS IN 1956–7

A remeasurement was made 5–6 years later in 1956–7 when the height had increased to 26–35 feet (41 feet at Lael). The data from this measurement are given in Table III. The girths of the trees were then significantly larger in the heavily thinned plots but not so much as to compensate in basal area for the heavy reduction of growing stock. Examination of the crop at each thinning showed that the gaps caused by the previous thinnings were far from closing at the time when each further reduction of the number of trees took place. In some

experiments this was due to the incidence of die-back, which will be referred to later, but that explanation did not apply at Lael, and its importance is difficult to assess at the other forests. A further complication was that while the crops were young, the data for the number of trees included all that were present, while the data for basal area had, until recently, only been determined for trees in and above the 9 inch breast height girth class. This omits a varying proportion of

TABLE II. *First assessment. Mean girths of the largest 100 trees per acre (inches)*

Treatment and theoretical no. of trees per acre	*Loch Ard, Aug. 1951*	*Clashindarroch June 1951*	*Glentress Sept. 1951*	*Lael Nov. 1954*
A (200)	13·4	9·5	18·0	22·6
B (400)	14·2	9·2	16·7	21·4
C (600)	13·8	9·7	17·3	22·1
D (800)	14·0	9·3	16·3	19·6
E (unthinned to date)	13·2	9·4	15·3	19·1
F (unthinned)	..	9·4	14·7	..
Mean	13·7	9·4	16·8	21·0
Standard error ±	0·49	0·45	0·92	0·80
Differences.	Not sigt.	No sigt.	Not sigt.	Not sigt.

undersized trees, of which none was left in the most heavily thinned plots, but many (involving a substantial proportion of the basal area) in the less heavy thinning treatments, especially on poorer sites. Even after making allowance for these factors, it was clear that the more extreme intensities of thinning left much unused space between the trees.

At Glen Tress and Loch Ard a heavy growth of grass persisted in the heavier thinning treatments, while at Clashindarroch the heather remained dominant and extremely vigorous except in the less heavily thinned plots. Only at Lael, where thinnings were delayed, and the growth of the larch was extraordinarily fast, did the tree crop gain control of the ground vegetation.

Comparison of crop densities can be conveniently made by the use of a spacing index, and the simplest is the mean distance between the trees expressed as a percentage of the top height of a crop (Hummel, 1953). The normal number of trees per acre in European larch according to the published yield tables (Hummel and Christie, 1953) is about 800 per acre at a top height of 30 feet, and about 500 per acre at 40 feet, and these spacings are equivalent to indexes of 25 and 23 respectively. The same numbers per acre are quoted in the most recent thinning recommendations (Forestry Commission, 1958, p. 53). Table III shows that in the experiments at Loch Ard and Glen Tress the D grade thinning resulted in spacing indexes from 27 to 29 (the index of 35 at Clashindarroch is exceptional and resulted from gaps in the crop owing to die-back). The reduction in numbers to 400 trees per acre at such an unusually early age gave indexes of 33 to 41, while the most extreme reduction to 200 trees per acre only 2 years later resulted in indexes of 38 to over 40. Such thinnings are evidently far too heavy and in fact go beyond the definition of thinning, which is 'a felling made . . . without

TABLE III. *Latest assessment. No. of trees per acre (9-inch girth class and over), mean height of the largest 100 trees per acre (feet), mean girth of all trees 9 inches and over (inches), and their basal areas (sq. ft. per acre) excluding thinnings*

Treatment	Loch Ard, Achray Jan.–Mar. 1957. Age 21 yrs.				Clashindarroch Jan. 1957. Age 22 yrs.				Glentress Dec. 1956. Age 23 yrs.				Lael Dec. 1956. Age 19 yrs.			
	No.	*Ht.*	*Girth*	*Basal area*	*No.*	*Ht.*	*Girth*	*Basal area*	*No.*	*Top ht.*	*Mean girth*	*Basal area*	*No.*	*Top ht.*	*Mean girth*	*Basal area*
A	150	28·7 (>40)	18·3	22·0	195 205 (>40)	26·3	14·0	16·0	234	36·0 (38)	20·8	44·0	235	39·7 (34)	23·3	55·5
B	420	30·7 (33)	16·5	50·0	325 (400)	26·0 (41)	12·8	23·5	260	33·5 (38)	17·0	31·0	396	42·0 (25)	21·0	76·5
C	540 (610)	30·7 (28)	15·2	54·0	480 (580)	27·3 (32)	12·7	34·0	379	34·7 (31)	16·7	47·0	445	41·3 (24)	20·5	81·5
D	490 (500)	32·0 (29)	15·7	52·0	560 (745)	27·6 (28)	12·3	36·5	403	33·7 (31)	16·7	51·0	472	40·2 (25)	18·3	69·0
E (D grade thinning)	580 (595)	30·7 (27)	14·5	53·0	445 (470)	27·6 (35)	12·7	31·5	422	34·7 (29)	17·0	37·0	465	40·1 (24)	17·3	60·0
F (unthinned)	..	..	..	..	775 (1,720)	27·6 (18)	12·0	48·5	490	33·5 (28)	16·0	24·0	..	..	..	..
S.E. of means	..	0·97	0·32	..	..	1·06	0·36	..	..	1·10	0·60	..	..	..	0·34	..
Differences necessary for significance at																
levels of 5%	..	Not	1·0	..	..	Not	1·1*	..	..	Not	1·9*	..	..	Not	1·1	..
levels of 1%	..	sigt.	1·5**	..	..	sigt.	..	..	..	sigt.	..	..	..	sigt.	1·6**	..
Quality class	low III				low IV				III				I/II			

Figures in brackets give total numbers per acre and spacing index (mean spacing × 100/top height) including trees under 9-inch girth class. The number of trees under the 9-inch class was small except at Clashindarroch, and was neglected in computing mean girth and basal area.

* Differences significant at 5% level of probability.
** " " " 1% " " "

permanently breaking the canopy' (B.C.F.T., 1953), a permanent break being interpreted in sample plot practice as a gap which does not close over within a period of 5 or at most 10 years. However, indexes of 23–25 are rather low in modern practice, as thinnings are normally heavier in young crops than in the days when the crops on which the yield tables are based were growing, and a spacing index of 26 to 28 is now usual.

The results at Lael are different because, as noted above, thinnings were delayed so that only in the severer treatments were they exceptionally heavy. The very fast growth at this site also enabled the trees to catch up more quickly, and by 1956 only the severest thinning to 200 trees per acre was abnormal.

COMPARISON OF THE SOUTH AFRICAN AND SCOTTISH EXPERIMENTS

The method developed by O'Connor (1935) was explained in more detail by Marsh (1957). It applies to exotic species of pines planted at 1,200 per acre (spacing 6 feet by 6 feet). The reductions are made as soon as free growth ceases and competition sets in. This is defined by O'Connor thus: 'The moment the mean tree in a stand of a particular density starts to exhibit differentiation in crown or stem, as compared with the mean tree in a stand of lower density, then the trees in the stand in question cease to be free growing, and are starting to compete with each other.' Marsh described the experimental procedure. The mean diameter at breast height in the plots is determined annually. Its value for all the trees of a heavily thinned plot is compared with an equal number of trees selected in a more lightly thinned plot to give the same mean diameter. When this diameter falls by $\frac{1}{10}$ inch, in relation to the more heavily thinned plot, it is time for the next reduction in numbers to be carried out.

In the Scottish experiments no such control was instituted, and the reduction was an arbitrary one by number of stems per acre and time without regard to the growth of the trees. If a control related to growth response had been exercised, it is probable that the reductions in numbers would not have taken place so rapidly, nor would they have reached such low numbers per acre as in South Africa, at least in comparable times.

It is suggested that the main reason for the lesser response to heavy thinning is the slower growth of larch in this country as compared with exotic pines in South Africa. Even at Lael, an exceptionally fast growing larch site for Scotland, thinnings of such abnormal intensity are not compensated by adequate increases in girth and basal area. Another important reason is competition by ground vegetation. O'Connor based his proposals on the principle that the size attained by a tree is related firstly to the locality factors and secondly to the growing space available to it, but competing vegetation was only envisaged in a footnote stating 'should grass appear in any of the plots while they are kept free growing it would have to be removed'. It is evident that ground vegetation is an unimportant factor in South Africa, but in Scotland the suppression of grass, bracken, or heather is a primary consideration. For this purpose it is essential to let the crop close up to some extent, and this did not happen in the Scottish experiments. On sites where European larch is normally planted in Scotland control of grass or bracken is

Differences significant at 5% level of probability.
" " 1% " " "
" " " " " "

usually necessary. Control of heather may also often be needed, and this may be of even greater importance in the case of species such as spruces which are especially susceptible to check by heather. Pines, on the other hand, are less susceptible to competition from vegetation. As control of weeds by hand is expensive and control with the aid of machinery, oils, or chemicals is not yet generally practicable, control through the action of the tree crop itself is the only alternative.

TABLE IV. *Percentage of dead and dying trees*

Treatment and theoretical no. of trees per acre	*Loch Ard*			*Clashindarroch*		
	Actual mean no. of trees per acre	*Percentage*	*Angular transformation*	*Actual mean no. of trees per acre*	*Percentage*	*Angular transformation*
A (200) . . .	155	2·3	7·2	205	0	90·0
B (400) . . .	438	6·7	14·8	398	2·8	82·6
C (600) . . .	648	10·7	18·4	582	2·6	80·1
D (800) . . .	830	14·7	22·4	709	7·3	75·5
E (D grade or still unthinned) . . .	1,001	11·7	19·8	1,680	39·0	47·5
Standard error of means . .	..	..	±2·62	..	..	±3·63
Differences for significance at 5% level	..	..	8·5	..	..	11·8

The common practice of ploughing before planting changes the situation somewhat. Removal of competitive vegetation and the activation of the soil caused by the cultivation ensure rapid growth of the trees at the start, but a race frequently ensues between the trees and the re-invading vegetation. It is essential, if tree growth is not to suffer a check, to make sure that the canopy closes early and tightly enough to prevent the re-invasion of ground vegetation.

These preliminary experiments indicate that the optimum intensity of thinning, for maximum quick volume production per acre, is likely to be that which gives the trees the maximum growing space commensurate with control of competing vegetation.

THE EFFECT OF HEAVY THINNING ON DIE-BACK AND CANKER

Die-back and disease occurred in three of the four experiments, only that at Lael escaping the malady. No data are available from the experiment at Glen Tress as the numerous dead and dying trees had been cut out before assessment. In two of the experiments (Loch Ard and Clashindarroch) the number of dead and dying trees was counted in the spring of 1956. In the plots thinned to D grade (treatment E), normal suppression may have been the cause of death, but in the heavily thinned plots, especially the most severe treatments where the trees were completely isolated, the cause cannot be other than the susceptibility of the trees to the complex of frost and fungi (species of *Trichoscyphella* [*Dasyscypha*]) which causes die-back and canker. Table IV shows that the incidence of die-back is

more or less inversely correlated with heavy thinning. This is to be expected, as the heavier thinnings remove more of the poor trees, leaving smaller percentages composed of the best individuals. The lower percentage of dead or dying trees in the heavily thinned plots is thus a measure of the selectiveness of the thinning and does not prove that the thinning has increased the resistance of the trees to die-back. Even reduction below 200 trees per acre did not always result in the elimination of die-back.

TABLE V. *Percentage of trees without stem canker* (*Dominants and co-dominants only*)

Treatment and theoretical no. of trees per acre	*Loch Ard*	*Clashindarroch*	
	Percentage	*Percentage*	*Angular transformation*
A (200)	1	17·7	23·2
B (400)	0	15·3	21·0
C (600)	0	10·0	14·8
D (800)	0	5·7	11·2
E (D grade or still unthinned) . . .	1	4·3	7·0
Standard error of means			7·72
Differences			Not sigt.

Assessment of the number of trees with cankers on the stems was also made in 1956. At Lael none was found under any degree of thinning. At Glen Tress it appeared that the cankers were confined to trees of one of the two races of larch which had been mixed in the experiment. At Loch Ard all trees in all plots, with very few exceptions, were cankered. Evidently thinning did not affect cankering in these experiments. Only at Clashindarroch was there an apparent difference between treatments, where the percentage of trees without canker was higher in the heavier grades of thinning (Table V), but the differences between individual plots were very variable and they are not statistically significant. As in the case of the dead and dying trees, the higher proportion of uncankered trees is a measure of the selectiveness of the thinning in which cankered trees were removed where possible. If the proportion of trees not susceptible to die-back and canker is below some 10 to 15 per cent., it follows that repeated thinning leaves a healthy crop.

ACKNOWLEDGEMENT

The experiments were carried out as part of the Research Programme of the Forestry Commission and the results are published by permission.

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THE BRITISH ASSOCIATION, 1959

THE Association will meet in York from 2 to 9 September. Mr. W. R. Day is Chairman of the Forestry sub-section and Mr. T. V. Dent the local Honorary Secretary. Topics and speakers include the following.

Work Study. Professor Ulf Sundberg (Sweden), and Messrs. J. W. L. Zehetmayr and R. E. Crowther.

Deer in Britain (joint session with Zoology). Messrs. H. A. Fooks and J. S. R. Chard.

The Value of Forest Shelter in Agriculture (joint session with Agriculture). Professor J. E. Nichols, Dr. Caborn, and Mr. A. R. Wannop.

Decay in Standing Trees. Dr. W. P. K. Findlay and Messrs. J. D. Low and H. G. Dowden.

Full-day excursions are to the North Yorkshire moors for research experiments on Broxa Heath and in Allerston Forest, and to the eastern Pennines for Lord Bolton's Wensleydale estate. Half-day excursions are to the Vale of York for Forestry Commission plantations at Sand Hutton, to the Yorkshire Wolds for Sir Richard Sykes's Sledmere estate, and to the Hambleton Hills for private estates and Forestry Commission woods in the Ampleforth area.

Conditions of membership and further details from the Secretary, British Association, 18 Adam Street, London, W.C. 2.

HONOURS

THE names of the following members of the Society appear in the New Year Honours, 1959.

C.B.E. Mr. S. C. Longhurst. Forestry Commissioner, 1951–7. Past President Federated Home Timber Associations, and head of the firm of E. Longhurst & Sons Ltd., Epsom.

O.B.E. Mr. F. C. Ford-Robertson, Director, Commonwealth Forestry Bureau, Oxford.

THE SHRINKAGE OF RAYS AND FIBRES IN WOOD

By L. C. A. de S. WIJESINGHE

(*Forest Department, Ceylon*)

SUMMARY

1. Shrinkage was measured on sections of the woods of *Artocarpus integra*, *Canarium zeylanicum*, and *Acer pseudoplatanus*.

2. Shrinkage stresses between rays and fibres were demonstrated by drying radial strips of tissue containing rays on one side and fibres on the other.

3. Strains developed by these stresses were removed by dissection of the rays and fibres, which decreased the radial shrinkage of the rays and increased that of the fibres.

4. The difference between the radial and tangential shrinkage of the fibres was reduced, but not removed by separation from the rays, and this inherent anisotropic shrinkage of the fibres must constitute an important cause of the differential shrinkage of wood.

INTRODUCTION

THE differential or anisotropic shrinkage of wood is of great practical importance in seasoning, but in spite of this and of the amount of research it has attracted, is still not fully understood. Numerous hypotheses have been put forward, but the trend recently has been to concentrate on the influence of the rays in reducing radial shrinkage. Bosshard (1956), however, has recently re-emphasized the importance of the middle lamella of the fibres and tracheids. He considers that the degree of lignification of this layer plays a part in causing differential shrinkage in the cross-section in addition to the effect of the rays. The present investigation was limited to the difference between radial and tangential shrinkage. It was undertaken before Bosshard's work came to the attention of the author and it is of interest that, using different methods it led to a similar conclusion, namely that, although the rays are partly responsible, there is some other factor inherent in the fibres involved in the differential shrinkage of wood. The method of approach was to measure the shrinkage of rays and fibres that had been dissected out from sections and to compare these results with the shrinkage of these tissues in sections.

MATERIALS

The species used in this investigation were *Artocarpus integra* Merr., Moraceae, *Canarium zeylanicum* Bl., Burseraceae, and *Acer pseudoplatanus* L. (sycamore), Aceraceae. Material of the first two species consisted of dry specimens from the wood collection at the Imperial Forestry Institute, Oxford, the *Artocarpus* specimen from India and the *Canarium* from Ceylon. These were selected as lacking growth rings and the *Artocarpus* to represent a wood with moderately abundant parenchyma and medium-sized rays, and the *Canarium* a wood with no parenchyma and fine rays. Recently felled material of local sycamore was added, primarily in order to provide 'green' samples in which there would be little likelihood of 'set'. The wood has a simple structure with no parenchyma and wide

rays. As the sycamore has distinct growth rings, the material for measurement was all taken from the early part of the ring.

METHODS

Small cubical blocks were saturated by soaking in warm water and drawing a vacuum. Microtome sections 14μ thick were then cut from the blocks in the transverse and radial planes. The sections were mounted in water. The cover glass was supported at the two ends by slips of paper pasted on the slide by a water-insoluble glue. Mounted in this way, the sections have freedom of movement and at the same time are prevented from curling. The slides were placed in an oven at 60° C. for a few hours and then transferred on to the laboratory bench for an hour, after which the measurements were made. This procedure was adopted instead of oven drying to avoid the problem created by the very rapid absorption of water by oven dry sections. Measurement of the sections was made under a microscope using a graduated scale in the eye-piece.

EXPERIMENTS AND RESULTS

Shrinkage of transverse sections

Transverse sections were trimmed, mounted, and dried as described above. The radial and tangential dimensions of the sections were measured dry and after saturation with water. The rays often projected slightly on the tangential edges of the sections in the dry specimens, and for this reason the line of measurement in the radial direction was always located between rays and not along them. The percentages of radial and tangential shrinkage were then calculated, based on wet dimensions. For each section the ratio of tangential shrinkage to radial shrinkage (T/R) was determined, and the mean of all the sections calculated for each species. The results are given in Table I.

These results show that all the woods exhibit differential shrinkage, the T/R ratio varying from about 1½ to 2, the greatest difference between radial and tangential shrinkage being found in *Artocarpus*.

Stresses between rays and fibres

(i) *Shrinkage of fibres attached to rays.* Transverse sections were dissected to give strips containing fibre tissue on one side and ray tissue on the other (fine rays in *Canarium*, 4–5 seriate rays in *Artocarpus*, and 6–7 seriate rays in sycamore). In *Artocarpus* and *Canarium* the strips were cut so that the tissue adjacent to the ray contained fibre tissue only, and in this respect differed from similar strips used by Lindsay and Chalk (1954) and McIntosh (1954, 1955), where vessels and parenchyma were included. In sycamore the high proportion of vessels in the wood made it difficult to exclude them altogether from the strips; but it was possible to obtain sufficiently long strips that included only parts of vessels.

On drying, these strips bent in the manner expected, with the ray on the outer or convex edge, thereby showing that both the fine rays and broad rays exert a restraining influence on the radial shrinkage of the fibres. Curvature was very marked in *Artocarpus* and *Canarium* (Figs. 1 and 2). In sycamore the width of the rays made it possible to cut a series of strips with varying proportions of fibre and

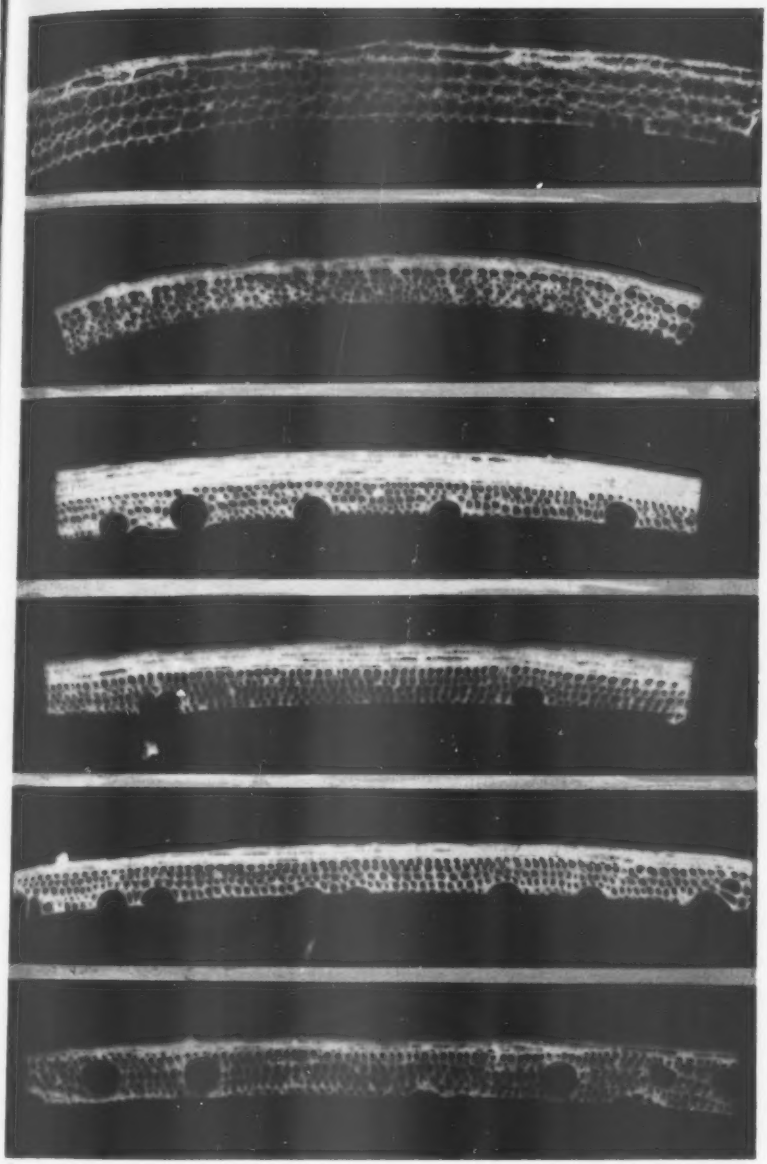

FIG. 1. *Canarium zeylanicum* (×94). FIG. 2. *Artocarpus integra* (×56). FIGS. 3–6. *Acer pseudoplatanus*, with different proportions of ray tissue (×56). Strips of tissue dissected from wet cross-sections so as to include ray tissue on one side and fibres on the other, and subsequently dried. The curvature indicates the lower radial shrinkage of the ray tissue.

PLATE VI

ray tissue. The behaviour of the strips is shown in Figs. 3–6, in which it can be seen that maximum curvature is associated with the highest proportion of ray tissue, although the differences in curvature between the strips are very small.

TABLE I. *Radial and tangential shrinkage of transverse sections*

	Radial shrinkage (R)	*Tangential shrinkage (T)*	*T/R*
	%	%	
Artocarpus . .	3·75	7·24	1·93
Canarium . .	3·38	5·08	1·50
Sycamore . .	4·28	6·40	1·50

Even the maximum curvature is small compared with that in the other species, although this species has the broadest rays.

These experiments clearly demonstrate the stresses developed on drying between rays and fibres. The rays in all three species have a restraining influence on the radial shrinkage of the fibres, but the differences between species do not appear to bear any relation to their ray size.

(ii) *Shrinkage of rays.* The next step was to compare the shrinkage of rays in sections and when isolated from the other tissues of the section. Transverse sections were prepared and mounted and radial measurements of rays made along

TABLE II. *Shrinkage of rays*

	Radial shrinkage (R)		*Axial shrinkage (A)*	*A/R*
	In whole sections	*Isolated*	*Isolated*	*Isolated*
	%	%	%	%
Artocarpus . .	1·84	1·29	2·28	1·77
Canarium . . .	3·24	0·20	..	..
Sycamore . . .	4·07	3·78	3·27	0·87

the same lines of cells in the dry and wet state. It was not practicable to dissect out the small rays of *Canarium* from transverse sections, and radial sections were therefore used for all three species for the dissection of the rays. The difficulty of sectioning the fine rays of *Canarium* and their low radial shrinkage (0·2 per cent.) when isolated suggested that there might be some incipient decay in this tissue, and careful inspection under the microscope gave some evidence that this might be so in a few of the rays, but the fibres appeared to be unaffected. For the same reason it was difficult to obtain the axial shrinkage of these fine rays and no figures for axial shrinkage are given for *Canarium*. The mean values for each species are given in Table II.

It is clear from these results that the radial shrinkage of rays is less when dissected out than in the intact section. Evidently the rays are being compressed

by the greater radial shrinkage of the fibres. The figures for radial shrinkage in whole sections given in column 1 of Table II above differ from those in column 1 of Table I. This is because in Table I the measurements were made in between the rays whereas Table II is based on the measurement of the rays. It is the difference between these two rates that causes the rays to project on the tangential edges of dry sections, as has been noted by several authors. There is considerable variation between the three species in the behaviour of the dissected rays. The high radial shrinkage of isolated rays in sycamore is noteworthy; it is even higher than their axial shrinkage.

Comparison of the shrinkage of transverse section of fibres when in complete sections and when isolated

In order to find out whether the stresses demonstrated in the previous section are the sole cause of differential shrinkage it was decided to make a quantitative study of the shrinkage of fibres while attached to rays in sections and when isolated from them.

TABLE III. *Shrinkage of fibres in whole transverse sections*

	Radial shrinkage (R)	*Tangential shrinkage (T)*	*T/R*
	%	%	
Artocarpus . .	3·94	8·02	2·04
Canarium . .	3·65	5·53	1·52
Sycamore . .	4·58	7·62	1·66

(*a*) *Fibres in complete sections.* Transverse sections were mounted and dried as in the previous experiments. Radial and tangential rows of fibres were measured dry and saturated, under a $\frac{1}{6}$ objective. Rough sketches were made to help to identify the points of measurement. Radial rows immediately adjoining rays were avoided, but otherwise the selection was random. The means of these measurements are given in Table III.

In all three species the fibres exhibit differential shrinkage with T/R ratios ranging from 1·5 to 2·0. This is contrary to the results obtained on several hardwoods by Clarke (1930), who found that the fibres exhibited isotropic transverse shrinkage and that the parenchyma and vessels were distorted to compensate for the higher rate of radial shrinkage of fibres as compared with wood as a whole.

(*b*) *Isolated fibre tissue.* Radial strips of fibre tissue were dissected from saturated transverse sections using a razor blade. In *Canarium* and *Artocarpus* all other wood elements were excluded from the strips. In sycamore vessels were so numerous that some were often included; but, as the main purpose of this experiment was to test the effect of the rays on the shrinkage of fibres, it is unlikely that the presence of a few vessels would appreciably influence the result. The strips of tissue were mounted, dried, and measured as in the previous experiment. The mean values are given in Table IV.

In all three species radial shrinkage of the fibres was increased as a result of

removing the rays, but there was still a marked difference between the radial and tangential rates of shrinkage in the fibres, with T/R values well above 1·0. There were some inconsistent and inexplicable differences in the values recorded for tangential shrinkages in each species which make difficult a direct comparison of the T/R values in Tables III and IV. To overcome these difficulties a further series of measurements was made on *Artocarpus* and sycamore, in which the same fibres were measured dry and wet, *in situ* in a section and after dissection. The

TABLE IV. *Shrinkage of isolated fibre tissue*

	Radial shrinkage (*R*)	*Tangential shrinkage* (*T*)	*T/R*
	%	%	
Artocarpus . .	4·76	7·53	1·58
Canarium . .	4·04	6·03	1·48
Sycamore . .	4·92	7·42	1·51

TABLE V. *Radial and tangential shrinkage of fibres* (*a*) *when associated with rays, and* (*b*) *when isolated from them*

	Radial shrinkage (*R*) (%)		*Tangential shrinkage* (*T*) (%)		*T/R*	
	Fibres in sections	*Fibres isolated*	*Fibres in sections*	*Fibres isolated*	*Sections*	*Isolated*
Artocarpus . . .	4·50	5·55	7·90	8·20	1·76	1·48
Sycamore . . .	5·41	6·15	..*	10·15	1·88	1·65

* Inadvertently no drawing was made of a tangential row of fibres in sycamore before the dissections were performed. As no appreciable difference in the tangential shrinkage was anticipated, or was in fact found in *Artocarpus*, the figure 10·15 per cent. for the tangential shrinkage of the isolated fibres has been used in calculating the T/R ratio of 1·88 in the entire section.

measurements were made on tracings of highly magnified images (×1500), as this was found to give more accurate results than direct measurements under a microscope. The results are shown in Table V.

These experiments demonstrate clearly that the rays have a restraining influence on the radial shrinkage of the fibres in sections, but that this cannot be the whole explanation of the difference between radial and tangential shrinkage, as the fibres still exhibit anisotropic shrinkage when isolated. This inherent anisotropic shrinkage of fibres must be an important contributory cause of differential shrinkage of wood.

DISCUSSION

Measurements of the radial shrinkage of rays and fibres in complete sections and when dissected free of other tissues showed that the radial shrinkage of isolated fibres is greater than that of the isolated rays in each species and that the overall shrinkage of any section is a compromise between these two rates. The

development of stress between these two forces is clearly shown in Figs. 1 to 6, which illustrate the distortion of strips containing ray tissue along one side when they are dried. The radial shrinkage of the isolated rays was approximately $\frac{1}{2}$ and $\frac{1}{4}$ that of the isolated fibres in *Artocarpus* and sycamore respectively; the rate was even lower in *Canarium*, but the reliability of this figure was open to doubt for the reasons discussed above.

The importance of the restraining influence of rays varied considerably in the different species. In view of the relation shown by McIntosh (1955) within a single species between the proportion of ray tissue and radial shrinkage, and the general relation shown by Chalk (1955) between the proportion of ray tissue in different species and ray width, it might have been expected that there would be some relation between the restraining influence and the width of the rays in the three species investigated. This was not borne out by the data for sycamore, which had the widest rays. Removal of the rays had the least effect in this species, the radial shrinkage of the fibres while still attached to the rays being 4·58 per cent. compared with 4·92 per cent. isolated. The corresponding figures for the two other species were: *Canarium* (narrow rays) 3·65 per cent. increasing to 4·04 per cent. and *Artocarpus* (rays up to 4- or 5-seriate) 3·94 per cent. increasing to 4·76 per cent. The relatively small influence of the large rays of sycamore appears to be due to the unusually high rate of radial shrinkage in its rays, which results in there being much less contrast than usual between the shrinkage of the rays and of the fibres. The shrinkage of the rays of sycamore is unusual also in the axial direction. The axial shrinkage (3·27 per cent.) in rays dissected from radial sections was slightly less than the radial shrinkage (3·78 per cent.). This recalls Ritter's (1939) work in connexion with the orientation of the micellar structure of ray cells in which he found that shrinkage of isolated rays was greater radially than axially. The effect of rays on radial shrinkage was greatest in *Artocarpus*.

The restraining influence of the rays on radial shrinkage might be expected to reduce the radial shrinkage of the fibres in sections, but Clarke (1930) found that the fibres in sections shrank evenly in all directions. This he explained on the grounds that the difference between the radial shrinkages of rays and fibres is taken up by distortion of the vessels and parenchyma cells, which become wider radially as the sections shrink. Similar distortion of the vessels was observed in the present investigation, but in addition the fibres themselves shrank less radially than tangentially. This difference between radial and tangential shrinkage rates in the fibres was reduced by removing the rays, but by no means entirely removed, indicating that, though partly due to the rays, it must also be the result of some factor inherent in the fibres themselves. The importance of this inherent factor may be judged by the T/R ratios of the isolated fibres, which were 1·6 in *Artocarpus*, and 1·5 in *Canarium* and sycamore. This result is directly contrary to the conclusion reached by McIntosh (1955). From the extrapolation of a curve representing the relation between percentage of ray tissue and radial shrinkage in Canadian beech he concluded that differential shrinkage in this species is almost entirely due to the influence of the rays. There seems, however, to be some possibility of error in the extrapolation of such a curvilinear relation.

There are several hypotheses that might explain such inherent differential shrinkage of the fibres, but there are serious objections to most of them. Ritter and Mitchell (1952) suggested that reduced radial shrinkage might be due to the disturbance of micellar structure in the radial walls by pitting. It is true that in *Artocarpus* and sycamore the fibre pits are predominantly located in the radial walls, but this is not true of *Canarium*. Frey-Wyssling (1940) attributed the greater tangential shrinkage of conifers to the occurrence of wider compound middle lamellae in the radial walls. Some evidence of wider lamellae in the radial walls was found in *Artocarpus* and the isolated fibres in this species had a slightly higher T/R ratio (1·6 compared with 1·5 in the other species). No differences, however, could be observed between the radial and tangential lamellae in the other two species. The hypothesis according to which differential shrinkage is accounted for by differences in the shrinkage of early wood and late wood (Hale, 1957; Pentoney, 1953; Vintila, 1939) cannot have any application to the differential shrinkage observed in the two tropical species without growth rings or in sycamore, in which measurements were all taken from the early part of the ring.

More recently Bosshard (1956) has stressed the importance of the degree of lignification of the middle lamella as one of the causes of anisotropic shrinkage and this might well be the explanation of the differential shrinkage of the fibres of *Canarium* and sycamore. These woods have relatively thin-walled fibres whose shrinkage might be expected, according to Bosshard's reasoning, to be dominated by the middle lamella. It has been shown above that in these two species removal of the rays had relatively little effect on the radial shrinkage of the fibres.

The behaviour of *Artocarpus* is not easy to explain on similar grounds. The fibres are thick-walled and their shrinkage should therefore be determined largely by that of the secondary wall and so be more nearly isotropic, whereas the T/R ratio (1·6) is slightly higher than in the other two species (1·5). However, it has already been noted that the compound middle lamellae in this species were thicker in the radial than in the tangential walls and this may possibly be the reason for the high T/R ratio.

CONCLUSIONS

This investigation supplies further evidence for the view of Bosshard (1956) that the anisotropic shrinkage of wood is due to at least two separate factors and demonstrates that, though the rays have a restricting effect on radial shrinkage, there is also some inherent cause of anisotropic shrinkage in the fibres. The relative importance of these factors appears to vary considerably in different species, particularly through differences in the rate of radial shrinkage of the rays.

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RALPH SNEYD PEARSON

Sir Ralph Pearson Kt., C.I.E., LL.D., who died recently, joined the Indian Forest Service from Cooper's Hill in 1898 and in 1909 was selected for charge of the Economic Branch recently formed at the Forest Research Institute at Dehra Dun. Before he left India in 1925 his work on timber preservation there had begun to gain general acceptance to the great benefit of Indian industry. He was appointed as the first Director of the Forest Products Research Laboratory in the Department of Scientific and Industrial Research and built up the organization on the lines of his branch at Dehra Dun and remained in charge there until his retirement in 1933. He wrote several monographs on forest products and his chief work was *The Commercial Timbers of India* written in collaboration with the late H. R. Brown of the New York State College of Forestry. He was knighted in 1933, was an LL.D. of St. Andrews University, and was President of this Society in 1931 and 1932. A good shot and keen cricketer, he was always very popular with his staff. He is survived by two sons and a daughter. W. A. R.

THE PREPARATION OF PRICE INDEX NUMBERS FOR FORESTRY PRODUCTS

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SUMMARY

Only where internal factors are fairly constant can it be assumed that price changes are due to external factors of supply and demand and therefore of economic interest. To devise a satisfactory series of index numbers, the sources of data must be broadly based, a suitable base year must be found, the quality of the product must be reasonably constant, and, when necessary, 'weighting' must be applied. Some series of prices for home-grown forestry products have been tabulated and the intricacies of their preparation are discussed. The series chosen are those thought best qualified to provide a measure of price trend. Four tables have been added to show the relationship between home-grown and imported products.

INTRODUCTION

Consistency of the internal factors of a comparison. In their studies of prices Lord Beveridge and others (1939) have drawn attention to the important fact that prices are affected by two distinct factors: those that are internal and those that are external to any bargain. The internal factors include such things as the quality and quantity and terms of sale, i.e. whether wholesale or retail, inclusive or exclusive of delivery to buyer's premises, inclusive or exclusive of charges of various kinds for cash or for credit. The external factors relate to the condition of demand and supply. It is when price movements are due to changes in the economic structure that they become important to the economist and the historian. Fruitful comparisons can only be made when it is assumed that the internal factors are substantially the same for the prices compared. Where the internal factors are fairly constant then it can be assumed that changes are caused by changes in the external factors.

On previous occasions the author of this article has drawn attention to the difficulty in measuring the trend of home prices because there are usually so many variations in the internal factors (MacGregor, 1950, 1953*a* and *b*). These variations are greatly reduced when it is possible to obtain series of data for products which are more or less of standardized quality and specification. The price index numbers for a series of such products have been brought up to date in the various tables in this article.

Theoretical requirements of a satisfactory index number. There are several theoretical requirements of a satisfactory index number: the sources of the data should be broadly based, a formula has to be devised to give the more important items more weight than the less important, a high degree of consistency should exist in quality or specifications of the products, and a suitable base period should

be chosen for the percentage measurements. While these considerations apply more where an attempt is being made to measure broad changes in a number of closely related commodities, as for a cost of living index, they would not all apply to an individual product unless an attempt was being made to get a broad measure of change for the prices of an industry as a whole.

There are many categories of timber products which have widely different supply and demand conditions. Some may have an increasing demand, some a relatively stationary, and others even a decreasing demand. Elasticity of demand is greater for some products than others, and this means that the demand for them is more sensitive to price changes than for other products.

There are some advantages in taking 1938 as a base year: it was the last complete calendar year before the war of 1939–45, and it thus provides a contrast with the period of war and the immediate post-war years, and the whole 10-year period of price control from 1939 to 1949. There are certain disadvantages in having a base year which is too far away in time, but comparison can be simplified and made more interesting if the base period comes before the patterns of economic activity show marked changes.

Special problems in forestry. Apart from the effect of variations in quality, regional prices are influenced by differences in demand and distance from markets. In these circumstances delivered prices can probably provide a more useful standard for judging the degree of fluctuation than can standing timber prices. At the same time tendencies are developing towards forward pricing contracts—as for mining timber—and these tendencies are probably likely to obtain more and more in the future. Government departments tend to order on specification and contract.

The problem of finding constant quality is rather obvious with most domestic timber products, particularly in the absence of grading, and the author here has limited his choice to those products which have some degree of standardization and specification. It is realized of course that in time of war, or scarcity, relaxation of specification may be inevitable. For some quotations and series of data it has been necessary to apply some form of weighting and this is described later.

In historical comparisons or economic assessments the relationship between costs and prices is of great significance. On the one hand, it was found that long-term data on wages are fairly well recorded but on the other hand series of comparable prices are much scarcer. The preparation of the present article has been prompted to some extent by a recognition of these special difficulties and features of timber price comparisons. As far as possible the prices of timber products which are now reviewed have been chosen because there was a relatively high degree of consistency in the internal factors affecting the series over a sufficiently long period to provide some measure of price trend.

Relationship between home-grown products and imports. At the end of the paper will be found four tables showing the relationship between home-grown products and imports. These are necessary for the appreciation of price trends of home-grown products.

POLES: ROUND SOFTWOOD CATEGORIES

It has been possible to obtain a long series of data from a large purchaser relating to four different size categories of a highly standardized softwood timber commodity. The series starts in 1914 and shows annual data—with the exception of 1926—up to 1957. As the information has been received in confidence it is not possible to indicate precisely the commodity covered in the four categories, but this is not a very great drawback for the purpose of an index number. Although the total quantity of timber involved is not high by comparison with pitwood as an outlet for private estates it may be of importance for individual properties.

During the Second World War a certain amount of relaxation in standards of quality were made over such specifications as knots, depth of sapwood, and deficiencies in heartwood.

The data are given in Table I together with data for railway sleepers.

RAILWAY SLEEPERS

A series of prices for coniferous railway sleepers f.o.r. at Scottish stations from 1890 to 1936 has been given by one long-established supplier to the railway companies. In order to fit it into Table I the period before 1914 has been omitted. It is worth mentioning, however, that in 1890 the index number was 47 but had fallen to 35 in 1894 whence it rose to 60 in 1901 but remained several points below 60 until 1912 when there was a steep rise from 53 to 68 and then to 74 in 1913. From 1936 onwards supplementary data have been obtained for softwood sleepers f.o.r. and these cover the period of war-time price control and the more recent years.

After 1921 the length of sleeper was reduced from 9 feet to 8½ feet as it was apparent, from a practical point of view, that the shorter length was just as satisfactory and represented a significant saving in shipping space for imported sleepers.

After price decontrol at the end of 1949 there was little activity in the production of home-grown sleepers (at any rate up to the autumn of 1951). This was thought to be due to a general shortage of home-grown softwood round timber causing producers to concentrate more on the smaller sizes of board, which enabled them to employ their saws to a greater extent than in producing sleepers. At this time it was argued by the railway department that better prices prevailed for sawn timber of other specifications, particularly for packing-case timber.

RAILWAY WAGON TIMBER

Many of the component parts used for railway wagons represent a standardized sawn timber product. The writer has been fortunate enough to obtain from the Federated Home Timber Association a source of annual prices for such components as oak scantlings (i.e. headstocks, solebars, small sizes, &c.) for the period from 1924 and more recently for bottoms and sheetings. During the period of price control the sales applicable to town mills have been taken as being more representative of the general run of the trade. The classification of country mill

TABLE I. *Home-grown timber*

(Index numbers 1938 = 100)

Year	Four categories of standard product*						Railway sleepers†
	A	*B*	*C*	*D*	*Average*	*Species*	
1914	55	64	65	66	63	S.P.	70
1915	61	66	65	65	64	Larch, Scots fir.	88
1916	57	60	..	..	..	Larch.	131
1917	125	150	145	135	139	Larch, Scots fir.	167
1918	125	150	145	135	139	Larch, Scots fir.	157
1919	120	124	126	116	122	Larch, Scots fir.	189
1920	192	195	133	142	157	Plain and rough.	189
1921	118	120	147	167	138	Larch.	189
1922	84	87	..	..	..	Not known.	90
1923	65	69	..	..	..	Scots fir.	93
1924	85	88	87	89	87	Larch.	100
1925	90	94	88	88	89	Scots fir.	100
1926	..	..	..	..	..		105
1927	88	92	85	88	88	Not known.	94
1928	75	76	69	70	72	Not known.	100
1929	66	..	67	70	68	Not known.	103
1930	87	87	87	89	88	S.P.	111
1931	73	80	75	76	63	S.P.	91
1932	68	73	72	73	71	S.P.	89
1933	66	69	75	76	72	S.P.	86
1934	68	72	75	76	74	S.P.	100
1935	76	82	83	82	81	S.P.	100
1936	74	78	78	79	78	S.P.	100
1937	95	99	99	101	99	S.P.	100
1938	100	100	100	100	100	S.P.	100
1939	101	106	117	120	113	S.P., C.P., larch.	100
1940	102	107	126	128	118	E.L., S.P., Scots fir, C.P., D.F.,	125
1941	102	107	126	128	118	Weymouth pine.	159
1942	127	136	129	129	130		181
1943	127	136	129	129	130	E.L., C.P., S.P., Weymouth pine,	210
1944	127	136	129	129	130	D.F., N.S., spruce, home-grown	219
1945	127	136	129	129	130	softwoods, approved species.	224
1946	127	136	129	129	130		225
1947	158	170	160	160	162		270
1948	158	170	160	160	162	Scots fir, pine, larch, C.P., D.F., S.S.	286
1949	158	170	160	160	162		284
1950	211	228	208	226	218	Larch, N.S., E.L., S.P.	400
1951	261	273	268	267	267	S.P.	456
1952	352	374	353	360	359		524
1953	314	335	304	294	312	S.P., N.S., larch, D.F., Weymouth	456
1954	296	324	296	379	324	pine	456
1955	349	382	356	365	363		495
1956	305	334	300	306	311	S.P., N.S., larch, D.F., Weymouth	514
1957	322	351	325	323	330	pine.	533

* Peeled.

† Softwood f.o.r. at Scottish Stations.

S.P. = Scots pine. C.P. = Corsican pine. E.L. = European larch. D.F. = Douglas fir.
N.S. = Norway spruce. S.S. = Sitka spruce.

was adopted during the period of control and had virtually disappeared in the early fifties. This distinction was recognized for negotiating wage rates, but since decontrol has been dropped the town and country mill rates are now the same. These prices are given in the first five columns of Table II.

More recently a combined weighted index number of prices on a monthly basis for other categories and species of railway wagon timbers has been prepared by the F.H.T.A., with June 1949 = 100, and the annual average since 1950 is shown in the right-hand column of Table II. Framing timber (i.e. headstocks and other scantlings) is to be distinguished from bottoms and sheetings in the various components of a railway wagon. Bottoms and sheetings do not require such a good quality of timber as would be used for wagon framing timber. When it is difficult to sell poorer grades of hardwood it can be expected that the prices for bottoms and sheetings would decline more than for wagon framing timber. The future of this trade is likely to be affected by the rate at which substitution is being made in the railways towards steel wagons, but as long as repairs to wooden wagons continue this will create a demand for the classes of timber included here. Although not shown in the table the monthly index numbers show a substantial fall from April 1957 onwards. This is explained in part by the fact that the weighting system previously used was then changed in accordance with the pattern of orders. This meant—with a falling off in the usage of wagon framing timber, especially solebars and side-rails—that a greater weight was given to bottoms and sheetings which had shown a relatively greater price decline. The weighting then became solebars and side-rails 10; headstocks 45; other scantlings 45; and bottoms and sheetings—hardwoods 50, softwoods 50.

F.H.T.A. INDEX OF HOME TIMBER PRICES

This has been mainly prepared by the F.H.T.A. in the course of supplying the Statistics Division of the Board of Trade with monthly prices for round and sawn timber. Timber prices were only a part of the Board of Trade's general index of wholesale prices, and it therefore seemed appropriate for the F.H.T.A. to prepare the timber data for a separate index. After decontrol at the end of 1949 price movements varied in different ways according to districts, species, and quality. These factors were recognized in the system of weighting.

For species the weighting was based according to the proportions in the 1947–9 Census of Woodlands of the four species, oak, ash, elm, and beech, which were 63, 13, 3, and 21 per cent. respectively. For the purpose of the index, in the absence of any alternative measure, it was assumed that the demand for these species was in the same proportion. While this might tend to over-estimate the importance of certain species this was not regarded as likely to lead to serious distortion from the statistical point of view so long as over-estimation was not of a significant amount, say more than 20 per cent. Conifers have been weighted with larch at 24 per cent. and other conifers at 76 per cent., and the ratio of hardwoods to conifers has been put at 9 to 1. These arrangements mean that the price of oak in England and Wales will have major significance on the index.

In the index, timber (excluding thinnings) and pitprop timber have been

TABLE II. *Index number of delivered prices of railway wagon timber*

Year	Oak scantlings (1938 = 100)				F.H.T.A. index¶ (1949 = 100)
	Headstocks	Solebars	Small sizes	Combined average	
1924	118	89	110	105	..
1925	109	83	100	96	..
1926	98	80	88	88	..
1927	95	89	97	94	..
1928	98	85	92	93	..
1929	98	83	95	91	..
1930	97	88	89	91	..
1931	88	81	75	82	..
1932	89	70	80	79	..
1933	86	71	73	74	..
1934	83	72	77	76	..
1935*	82	85	80	82	..
1936*	82	85	80	82	..
1937*	82	85	80	82	..
1938*, †	100	100	100	100	..
1939*	86	85	82	85	..
1940‡	147	150	150	149	..
1941	147	150	150	149	..
1942	147	150	150	149	..
1943	147	150	150	149	..
1944	147	150	150	149	..
1945	147	150	150	149	..
1946	147	150	150	149	..
1947	180	167	174	174	..
1948	215	202	209	209	..
1949	215	202	209	209	..
1950	258	257	265	260	112
1951	286	291	285	287	125
1952	303	294	295	297	132
1953§	247	260	252	253	115
1954	230	252	231	238	106
1955	217	255	237	237	110
1956	231	259	245	245	111
1957	231	260	259	250	106

* Prices quoted for 1935–9 were those suggested to members of F.H.T.A. and were not 'actuals'.

† In 1938, the base year, prices used were for the three categories headstocks, solebars, and small sizes were 5*s.* 6*d.*, 6*s.* 7½*d.*, and 5*s.* respectively.

‡ Owing to absence of full quotations for 'Railway' timber a switch was made to 'Wagon Repairers' for 1954 after making a link in 1953 for the continuation of the series.

§ From 1924 to 1949, at the end of price control, the prices are for January, from 1950 onwards for the averages of January, April, July, and October.

¶ Based on the monthly index prepared by F.H.T.A. for railway wagon timber, scantlings, and bottoms and sheetings.

included; it has been assumed that their ratio has been in the proportion of 4 to 1 and that first quality to merchantable quality has been in the ratio of 1 to 1. To allow for the fairly wide variations in the prices from area to area, the data have again been weighted according to membership and felling quotas in each of the F.H.T.A. areas. In the same way the weighting system developed for general use has been applied to the sawn hardwoods and then the weighting system developed between these three items has been used to complete the index, based on 30th June 1949 as 100.

These prices are given in Table III.

TABLE III. *Index of round and of sawn timber prices*
(30th June 1949 = 100)

	Round			*Sawn*			
*Date**	*Round timber (delivered Mill)*	*Pitprops (f.o.r.)*	*Weighted index†*	*Sawn timber*	*Wagon scantlings*	*Sawn mining timber*	*Weighted index‡*
1950	128	100	122	134	111	100	127
1951	112	127	115	131	118	100	125
1952	161	190	167	147	136	140	145
1953	115	166	125	133	121	123	131
1954	97	150	108	120	107	112	118
1955	101	146	110	133	106	112	128
1956	110	154	119	155	112	121	146
1957	111	154	120	154	111	119	145

* Relates to position in January except for 1950 when June is chosen.

† Based on weights of 80:20 for round timber and pitprops respectively.

‡ Based on weights of 77, 9, and 14 respectively for sawn timber, wagon scantlings, and sawn mining timber.

MINING TIMBER

For a long historical review of prices the author was advised by the National Coal Board that it would be best to think in terms of the pitprop position in Scotland and in South Wales as in these regions a large proportion of home-grown timber was used in the inter-war years. Another source of information relates to the rest of England and Wales where it is possible to follow the movement of prices in the period of maximum price control from 1939 to 1949 and to link these up with current agreements started in December 1921 between the National Coal Board and the F.H.T.A.

Price changes for home-grown pitwood unpeeled in South Wales. A long series of prices for South Wales are shown in columns 1 to 5 of Table IV from 1914. From 1947 to the end of 1949, when price control ceased, there was no alteration in the prices paid for South Wales pitwood.

One of the big problems in constructing an index number of prices is how to measure the effect of changing transport allowances, e.g. in 1950–1 carriage over 10*s.* per ton was payable by the National Coal Board and delivered prices were quoted until 30th November 1952. From 1st December 1952, prices were

f.o.t. with maximum carriage payable by the Board at 30*s.* per ton until 30th June 1956 when it was raised to 35*s.* From 1st July 1957 to 30th June 1958 maximum carriage became 38*s.* 6*d.* per ton. Since 1951 no special prices have been negotiated for larch in the agreements with the F.H.T.A. although special prices were negotiated separately with individual suppliers for the species when it was occasionally offered in full wagon loads. During recent years any larch supplied to South Wales collieries has been mixed in with other conifers and bought at 'other conifers' price. Since 1953 special prices have been arranged for softwood lagging F.O.T. Prices have not been arranged for hardwoods since 1954.

Period of maximum price control 1939–49, England and Wales. In 1939 under Regulation 55 of the Defence Regulations (Control of Timber (No. 1) Order 1939 (S.R.O. 1939, No. 1031)) a schedule of prices was fixed for round props delivered to mine sidings and premises in England and Wales. These were in two species categories and thirty-six size categories and quoted per 100 lineal feet. The sizes ranged from 2 inches cut to lengths up to 7 feet to 7 inches in 17-foot lengths. The price ranged from 5*s.* to 58*s.* and from 5*s.* 6*d.* to 66*s.* 9*d.* for the extremes for the two categories respectively: (1) 'Fir, &c.', and (2) 'Larch'. No distinction appears to have been made between peeled and unpeeled props. Subsequent arrangements distinguished between increasing numbers of size categories, between peeled and unpeeled and between 'other species' and 'larch and oak' (S.R.O. 1944, No. 920; S.R.O. 1947, No. 95; and Statutory Instrument 1949, No. 1075).

Price agreements for England between the F.H.T.A. and the National Coal Board. For about 2 years following the repeal of the Maximum Price Orders in December 1949 there was no general agreement in England for the purchase of pitprops by the National Coal Board and transactions were by individual negotiation.

In December 1951, however, a schedule of prices was agreed for the period to 31st December 1952 between the F.H.T.A. and the National Coal Board. Details of this basic agreement appeared in the *Quarterly Journal of Forestry* in 1952, pages 118–21. Thirty-seven categories on the same lines as the maximum prices orders were included up to 7 inches by 14-foot sizes, although larger sizes were subject to negotiation. Under this agreement the price schedule was based on a flat rate price of 5*s.* 4*d.* and 6*s.* per hoppus foot for unpeeled and peeled props respectively; prices were a greater increase over the 1949 prices for the larger than for the smaller pitprops.

As can be inferred from Table IV subsequent agreements ran for varying periods—the index numbers in the table are based on the average prices for each calendar year—and associated with these price changes, but not accounted for in the index numbers, were varying maximum carriage rates payable by the sellers of pitprops. The qualifications and definitions essential for the interpretation of the index numbers appear as footnotes to the table.

From 1951 to 1957 changes in the pitprop schedules were based on a flat rate or rate per hoppus foot. Sometimes there was one basis for 2½ inches to 4 inches and up and another for 4½ inches and up, while at other times there was only one basis for all diameters, e.g. in the agreement which came into operation on 1st July

1957, it was negotiated on the basis that prices ruling previously should be increased by 7 per cent. for 2½ inches to 4 inches tops and by 4½ per cent. for 4½ inches and over tops. From this date the agreement dropped any reference to unpeeled categories. In a recent year at English and Scottish collieries props up to and including 4-inch diameter represented 50 and 75 per cent. respectively of the total prop usage.

Although the index is based on 1938 = 100 it is an advantage in seeking a link with the later prices that there was no difference in the 1938 and 1939 levels in the South Wales series. This gives a direct link with the prices in the period of war-time control, operated from 1939 to 1949, and thus with the more recent agreements operated between the F.H.T.A. and the National Coal Board.

Since the first in December 1951 there have been six other contracts arranged between the National Coal Board and the F.H.T.A. for England and Wales covering the period up till 30th June 1959. The main changes affecting the prices index numbers are noted in the footnotes to Table IV.

For hardwood sawn mining timber in England and Wales there have been four agreements covering the period from 1st January 1953 to the end of December 1955 for the four categories of chocks, coverboards, lids, and tapered wedges. These are not included in the table of index numbers, but it is worth noting that these have shown declines since the prices ruling in 1952 of 23, 14, 11, 7 per cent. respectively.

For softwood sawn mining timber prices have varied with the specifications used and were a matter of arrangement between individual suppliers and the National Coal Board's different divisions and areas.

Home-grown mining timber in Scotland. The two index numbers for Scotland in columns 10 and 11 of Table IV provide a limited comparison with the Welsh series and also show in some measure the different price movements for sawn timber.

After the Control Order was revoked on 1st December 1949, home-grown mining timber prices in Scotland remained fairly steady until the official agreement was made in July 1950 between the National Coal Board and the Home Timber Merchants' Association of Scotland.

From May 1953 to June 1955 arrangements have been made between H.T.M.A. of Scotland and the National Coal Board for windblown sawn mining timber. Later from August 1955 to June 1957 and from October 1957 to June 1958 there were two other agreements for softwood covers and sleepers, and these showed slight rises of about 5 per cent. over the period covered by these arrangements.

RELATIONSHIP WITH IMPORTS

Proportion of total supplies from home-grown sources. Indirect comparisons may be made of the trend of the foregoing indices of prices for home-grown timber with those for imported categories. In order to put the relative proportions in perspective the percentage of home-grown and imported timber in total consumption is shown in Table V for the average of the immediately pre-war years and annually since 1940.

TABLE IV. *Index numbers of home-grown mining timber*

(1938 = 100)

Year	South Wales pitwood*					England pitprops§				Scotland mining timber	
						Other conifers and hardwoods		Larch and oak			
	Larch	Other conifers	Hardwood	Combined†	Softwood lagging‡	Peeled	Unpeeled	Peeled	Unpeeled	Round¶	Crown trees‖
	1	2	3	4	5	6	7	8	9	10	11
1914	77	65	65	69	..	..	..	..	..	50	80
1915	92	77	80	83	..	..	..	..	..	..	..
1916	138	115	100	117	..	..	..	..	..	..	..
1917	185	177	182	181	..	..	..	..	..	..	..
1918	185	185	182	183	..	..	..	..	..	..	..
1919	231	200	218	216	..	..	..	..	..	231	320
1920	277	246	236	253	..	..	..	..	..	..	..
1921	169	154	164	162	..	..	..	..	..	..	..
1922	138	138	145	140	..	..	..	..	..	..	..
1923	123	123	118	121	..	..	..	..	..	..	..
1924	123	123	118	121	..	..	..	..	..	..	..
1925	123	123	118	121	..	..	..	..	..	..	..
1926	123	123	118	121	..	..	..	..	..	..	..
1927	116	116	109	114	..	..	..	..	..	..	..
1928	100	100	100	100	..	..	..	..	..	..	..
1929	100	100	100	100	..	..	..	..	..	..	..
1930	100	100	100	100	..	..	..	..	..	59	85
1931	100	100	100	100	..	..	..	..	..	..	..
1932	100	100	100	100	..	..	..	..	..	..	..
1933	92	92	91	92	..	..	..	..	..	..	..
1934	92	92	91	92	..	..	..	..	..	..	..
1935	92	92	91	92	..	..	..	..	..	..	..
1936	92	92	91	92	..	..	..	..	..	..	..
1937	92	92	91	92	..	..	..	..	..	..	..
1938	100	100	100	100	..	100	100	100	100	100	100
1939	100	100	100	100	..	100	100	100	100	127	270
1940	191	170	182	181	..	100	100	100	100	127	330
1941	191	170	182	181	..	100	100	100	100	..	..
1942	191	170	182	181	..	100	100	100	100	..	..
1943	191	170	182	181	..	100	100	100	100	..	..
1944	191	170	182	181	..	105	97	103	100	..	..
1945	191	170	182	181	..	105	97	103	100	..	..
1946	191	170	182	181	..	105	97	103	100	..	..
1947	270	238	245	251	..	137	131	139	128	..	..
1948	270	238	245	251	..	137	131	139	128	166	360
1949	270	238	245	251	..	156	136	139	128	166	360
1950	270	238	245	251	..	156	136	..	..	166	360
1951	270	238	245	251	..	156	136	..	..	168	340
1952	..	335	325	325	..	312	269	..	..	220	540
1953	..	304	300	302	304	264	224	..	..	233	720
1954	..	282	268	275	277	245	204	..	..	270	655
1955	..	292	..	..	306	249	209	..	..	270	655
1956	..	292	..	..	317	255	216	..	..	277	655
1957	..	321	..	..	349	262	Not quoted	..	..	284	658

* From 1914 to 1949 incl.: freshly felled, unpeeled, delivered prices; 1951 the prices plus carriage over 10*s.* per ton; 1952–5 f.o.t.; maximum carriage paid by National Coal Board, 1.1.56 to 30.6.56 was 30*s.*, 1.7.56 to 30.6.57 was 35*s.*, and 1.7.57 to 30.6.58 was 38*s.* 6*d.* per ton for softwood lagging f.o.t. arrangements applied to 1955, then same carriage cost applied 1956.

† Unweighted average of index numbers.

[*Notes continued at foot of p.* 49.]

These data seem to show how, to a very large extent, reliance was placed on home-grown supplies in the war years and how, with the problem of building up a national reserve of standing timber, the softwood contribution returned to pre-war levels. Hardwoods and pitwood from softwood thinnings still provide a substantial proportion of total consumption.

TABLE V. *Home production and imported supplies, 1935–9 and 1940–57*

	Softwoods ('000 standards)				*Hardwoods (million cu. ft.)*				*Pitwood ('000 standards)*		
Year	*Home production*	*Consumed imports*	*Total*	*Home-grown %*	*Home production*	*Consumed imports*	*Total*	*Home-grown %*	*Home production*	*Total imports‡ Pitwood '000 standards (Gothenburg)*	*Home-grown %*
1935–9	113*	2,148	2,261	5·0	12·3	44·12	56·47	21·9	39	880	4·2
1940	177	709	886	20·0	22·3	25·5	47·8	46·5	597	433	59·0
1941	280	630	910	30·8	29·5	19·3	48·8	60·4	574	75	88·4
1942	298	478	776	38·4	41·4	16·3	57·7	71·5	637	11	98·2
1943	288	430	718	40·0	50·8	13·2	64·0	79·3	721	28	96·1
1944	196	605	801	24·5	47·0	11·2	58·2	80·6	602	74	88·9
1945	130	752	882	14·7	41·2	16·9	58·1	70·7	504	193	72·2
1946	88	988	1,076	8·2	38·0	19·0	57·0	66·6	338	552	38·0
1947	67	911	978	6·8	37·3	19·9	57·2	65·2	165	773	17·4
1948	65	1,046	1,111	5·9	40·8	21·6	62·4	65·5	195	652	23·0
1949	65	1,087	1,152	5·6	41·6	30·6	72·2	57·6	193	670	22·4
1950	53	973	1,026	5·5	37·4	59·5	96·9	38·5	177	438	28·8
1951	47	1,096	1,142	4·1	34·0	59·6	93·6	36·5	161	500	24·4
1952	38	1,056	1,094	3·6	30·3	39·3	69·6	43·5	245	852	22·2
1953	47	1,255	1,302	3·6	28·7	46·7	75·4	38·1	261	468	35·8
1954	57	1,477†	1,534	3·7	24·8	39·8†	64·6	38·4	329	417	44·1
1955	50	1,547	1,598	3·1	23·4	43·3	66·9	35·1	327	372	47·5
1956	45	1,462	1,506	3·0	21·1	40·7	61·6	34·1	339	387	47·0
1957	43	1,463	1,505	2·9	20·1	40·6	60·7	33·1	359	425	46·0

* Forestry Commission Census 1930 as there was no record of home production in the immediate pre-war years.

† The figures of consumption ('deliveries') of softwood and hardwood for 1954 are not comparable with earlier figures because of changes in the items and establishments covered.

‡ Import data for pitwood relate to Gothenburg standards of 180 cubic feet; other standards to 165 cubic feet. A breakdown of the total consumption of mining timber between home-grown and imported is not available, but for purposes of comparison it has been assumed that all home-grown timber is consumed during the year of production. 'Other pitwood' has been included in the figures of imports at the rate of 2½ tons of other pitwood = 1 Gothenburg standard.

Source: Board of Trade.

Trend of supply and price movements of imported timber. Some of the series of imported data go back more than a hundred years, but from time to time changes have been introduced in the Trade and Navigation Returns to show more categories as in 1920, and again in 1934, from which date twelve categories are differentiated as shown in Tables VI and VII. In one of a series of articles concerned with the sources and nature of statistical information in special fields of statistics (MacGregor, 1953 *b*) some aspects of these trends and movements have

‡ Softwood laggings have been started off in 1953 with the same index as 'other conifer' pitwood, i.e. at 304.

§ Per 100 lineal feet, 1939–44 delivered to mine sidings or premises, categories in col. 5 ('Fir & Co.'), in col. 6 (larch); 1944–9 delivered, categories in col. 5 (conifers and hardwoods, other than larch and oak), in col. 6 (larch and oak); 1951 onwards for 'mixed conifers', f.o.t.; from 1.1.53 sellers to pay carriage in excess of 35*s.* per ton; from 1.7.55 in excess of 38*s.* per ton, and from 1.7.57 in excess of 41*s.* per ton; in recent years average prices for calendar years. Periods for which contracts were arranged between F.H.T.A. and N.C.B. were successively: 17.12.51 to 31.12.52; 1.1.53 to 31.12.53; 1.7.53 to 31.12.53; 1.1.54 to 30.6.54; 1.7.54 to 30.6.55; 1.7.55 to 30.6.57; and 1.7.57 to 30.6.59.

¶ Per 100 lineal feet, 3 inches tops unpeeled; 1914–47 delivered; 1947–July 1950 includes cost up to 10*s.* per ton for sellers. Changes in the prices shown in cols. 10 and 11 were introduced after period of price control were 15.7.50; 1.7.52; 15.4.53; 1.7.55; 1.7.56; and 1.7.57.

‖ Delivered sawn 6 feet by 6 inches by 3 inches per cubic foot.

TABLE VI. *Volume of timber imports*

Year	Sawn soft	Sawn hard	Pit-props	Planed dressed soft	Sleepers	Box-boards	Hewn soft	Hewn hard	Veneers	Planed dressed hard	Staves	Tele-graph poles	Total imports*
	Total volume												
1938 Volume† '000 cu. ft.	244,275	30,747	103,392	49,149	19,340	14,625	17,926	4,218	617	3,699	1,996	2,218	492,202
	(1938 = 100)												
1957	95	88	52	9	64	35	85	321	166	5	21	92	74
6	83	81	47	9	81	35	78	278	166	4	15	122	67
1955	112	97	44	10	48	37	76	365	220	4	17	93	81
4	96	82	51	10	35	27	78	273	218	6	13	86	73
3	94	82	57	10	48	27	65	454	212	4	17	92	74
2	67	79	104	3	15	35	112	290	192	5	24	55	69
1	107	125	63	9	66	42	84	505	343	8	46	42	86
1950	51	135	53	5	49	33	71	368	208	3	41	102	55
9	69	75	82	12	61	32	32	291	159	3	30	108	65
8	55	63	79	14	50	27	143	378	206	4	46	61	61
7	73	67	94	27	86	33	207	268	215	3	47	61	78
6	47	29	67	16	25	23	62	138	136	4	14	24	46
1945	50	34	24	19	52	31	0·2	114	111	1	16	..	38
4	29	33	9	18	43	16	3	117	256	1	17	..	24
3	32	27	3	13	12	12	2	98	360	3	22	..	22
2	21	28	1	4	36	10	3	82	206	1	19	..	16
1	30	34	9	6	21	22	10	98	142	10	21	1	23
1940	47	70	53	47	10	41	45	130	135	26	26	6	49
9	84	89	77	107	59	87	47	75	88	92	56	64	83
8	100	100	100	100	100	100	100	100	100	100	100	100	100
7	141	152	174	103	122	112	98	101	119	127	165	87	142
6	136	127	85	118	74	101	77	94	107	109	155	107	118
1935	113	114	89	97	70	84	75	90	104	108	152	99	104
4	127	107	88	95	78	71	80	97	100	92	158	79	111

* Excludes 'other sorts'.

† The volumes for roundwood categories such as pitprops, hewn soft, hewn hard, and telegraph poles are estimated by reckoning standards and piled cubic fathoms at 99 and 151 cubic feet respectively.

TABLE VII. *Value of timber imports**

piled cubic fathoms at 99 and 151 cubic feet respectively.

TABLE VII. *Value of timber imports**

Year	Sawn soft	Sawn hard	Pit-props	Planed dressed soft	Sleepers	Box-boards	Hewn soft†	Hewn hard	Veneers	Planed dressed hard	Staves	Tele-graph poles	Total imports	Sawn hard: Mahogany	Sawn hard: Teak	Sawn hard: Oak	Sawn hard: Walnut
	Unit value																
Value per cu. ft. 1938	19·4*d.*	44·5*d.*	10·9*d.*	22·4*d.*	24·5*d.*	29·6*d.*	12·7*d.*	42·5*d.*	28·4*d.*	38·1*d.*	65·0*d.*	42·2*d.*	20·7*d.*	70·0*d.*	108·0*d.*	48·0*d.*	95·5*d.*
	(1938 = 100)																
1957	618	441	493	625	558	518	513	298	331	541	682	547	572	341	592	549	..
6	632	446	502	642	546	546	512	296	362	585	657	552	586	338	568	546	..
1955	621	429	470	617	471	522	476	280	343	614	670	511	579	298	456	548	..
4	572	413	388	582	402	505	441	284	316	477	744	494	525	279	413	524	..
3	572	399	441	586	449	487	450	290	275	601	655	579	524	271	457	433	..
2	654	449	632	659	572	627	548	313	289	674	611	626	555	296	538	475	..
1	655	400	520	574	477	582	525	332	257	443	581	400	598	314	552	433	..
1950	408	297	294	443	319	365	286	252	255	504	512	332	398	218	381	348	..
9	392	314	318	424	336	361	302	235	233	538	437	317	356	240	311	320	..
8	415	321	358	420	353	405	317	205	196	510	394	301	357	246	320	304	..
7	384	290	347	405	344	372	299	207	174	527	386	245	338	217	297	304	184
6	317	224	337	297	302	308	215	174	184	485	260	280	273	224	243	233	121
1945	286	208	288	272	272	320	890	155	133	365	321	..	284	118	..	219	88
4	331	211	257	293	273	345	717	170	140	255	311	..	341	141	..	227	86
3	320	210	250	294	250	285	685	179	124	231	300	238	341	153	..	234	96
2	268	184	257	246	222	251	277	161	111	194	309	240	298	189	110	193	76
1	256	171	214	203	180	236	217	141	106	187	252	205	254	143	105	171	91
1940	195	146	176	162	142	217	201	126	92	168	223	162	182	80	102	143	81
9	108	113	84	103	83	114	104	102	92	109	113	97	105	103	88	106	94
8	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
7	112	97	91	121	92	97	65	105	111	103	83	82	102	102	95	101	104
6	84	92	89	85	62	75	58	102	109	90	59	70	86	103	85	89	92
1935	77	87	86	80	62	68	55	91	101	84	41	57	80	104	78	89	93
4	85	87	78	91	61	80	60	91	101	92	39	54	84	99	78	88	87

* Based on Trade and Navigation Accounts.
† Includes roundwood logs.

been examined and it is not proposed to go into them again here. It is however pertinent to point out that for most categories of timber imports the index numbers of c.i.f. prices have risen relatively to much higher levels than those of the home-grown categories. At the same time the volume of some categories—notably sawn softwood, hewn softwood, and telegraph poles—in recent years have been restored to their pre-war amounts. Hewn hard and veneers are exceptional in that their volumes have greatly exceeded pre-war amounts.

The foregoing series of data have varied in length, but for the period from 1949 it is possible to show the price trend of ten separate home-produced categories and to compare these with the weighted average for all timber imports as follows:

TABLE VIII. *Price trend of timber categories, 1949–57*

(1949 = 100)

	1950	*1951*	*1952*	*1953*	*1954*	*1955*	*1956*	*1957*
Ten home-produced categories	117	122	162	148	157	143	150	155
All imported categories .	111	168	156	147	147	163	159	161

It is not possible to give a weighted average for the home-produced categories because the relevant volumes are not available. The main conclusion to be drawn from this short period is that home and imported timber have moved at similar rates which are slightly above those of retail prices of consumer goods and services in the same period.

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RURAL DEVELOPMENT SURVEYS IN SCOTLAND[1]

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SUMMARY

A review of the surveys being undertaken to secure the integration of forestry and agriculture, with an indication of the objectives, the methods employed, the difficulties encountered, and the results achieved. The attempt to secure full and sound land use is being made on a voluntary basis and progress is slow, but there is promise that forestry can be integrated with agriculture in hill areas with little or no loss in stock-carrying capacity, that the shepherd population can be retained in the glens and that the whole rural economy can be given fresh vigour. A major hindrance to rapid development of plans in survey areas is the lack of clear and demonstrable proof of the value of shelter and of well-founded directions on how best to obtain and maintain shelter, whether by belts or blocks.

INTRODUCTION

IT is not intended to discuss the nature and extent of the national forestry programme (recently reviewed by the Government), nor to argue the need for the maintenance of home food production. These may appear to be two conflicting interests. What the Rural Development Surveys show is that the conflict can to a very considerable extent be eliminated. The Department of Agriculture for Scotland and the Forestry Commission have in mind that agriculture and forestry ought not to be considered as if they were diametrically opposed to each other but should be regarded as very largely complementary.

ACQUISITION OF LAND FOR FORESTRY

We should first consider the normal ways of acquisition of land for forestry. Since the passing of the Forestry Act, 1945, all proposed acquisitions by the Forestry Commission in Scotland have been submitted to the Department of Agriculture for Scotland for examination and for agreement as to the areas that should be planted. The Department may, in some cases, withhold agreement to any planting at all, or may restrict its approval to the planting of particular areas the total acreage of which may or may not justify acquisition of the property as a whole by the Forestry Commission. Should agreement not be reached at departmental level, cases are submitted to a Minister for decision.

Amongst the agricultural factors which the inspecting officers take into consideration are the quality of the grazings, quality and health of sheep stock, lambing percentage, market prices, condition of permanent equipment (dwelling-house, steading, cottages, fences, &c.), accessibility of the farm and of the shepherds' cottages, and the labour position. The decisive practical assessment of the farm by the inspecting officer can be efficiently carried out only after considerable experience of such cases. The farmer is consulted as to the movement of the

[1] A paper delivered to a Joint Session of Agriculture and Forestry Sections of the British Association in Glasgow in September 1958.

sheep on the grazing, which ground is most essential in bad weather, and where shelter would be of greatest value. The 'downfalls' must be sufficiently wide to permit of easy and natural movement of the flock from the higher grazings with the oncoming of storm. Farmers may offer bracken-covered land and in some cases tick-infested land for planting. There is also the need to facilitate the agricultural use of the unplantable land; the importance of this will be more apparent when it is realized that the altitude to which planting can take place is not much more than 500 feet over a large part of the north and north-west of Scotland. Planting is carried out at much greater altitudes on the deeper soils farther east and south, but even there many acres may still be unplantable and would be sterilized by complete planting of the lower slopes.

When an estate or group of farms, rather than a single farm, is the subject of a proposed acquisition, it is generally easier to formulate a sound plan for allocation of land between forestry and agriculture and to retain the unplantable tops in agriculture. Contiguous areas on adjacent farms may form useful blocks for forestry, or one farm may go in large part to forestry, what remains of it in arable or rough grazing being added to a unit being retained in agriculture. Normally all enclosed lands are retained in agriculture, sometimes as forest workers' holdings. The acreage of arable, old arable, or enclosed land in the Highland area is so small in relation to the total area that a higher value has to be put on its retention than would appear to be justified by its quality.

The larger the area surveyed then, the easier, generally speaking, it is to minimize interference with agriculture. This fact alone would almost justify the use of the survey method. There are many other reasons for its use which can best be indicated by describing the pioneer survey.

STRATHOYKELL SURVEY

The Highlands and Islands Advisory Panel gave its backing in 1948 to the carrying out of a survey of quarter of a million acres covering the catchment areas of the rivers Oykell and Carron in the counties of Sutherland and Ross and Cromarty (Fig. 1). This is a hill-farming district varying in altitude from sea-level to 3,000 feet in the deer-forest areas. There is a small scattered population and the district is bare and windswept. Some fifteen estates are involved and there are approximately 150 agricultural subjects, the great majority of which are crofts with common grazings occupying a comparatively small portion of the total area. There are several large farms, some of which are tenanted subjects, but for the most part the farm lands are farmed by the proprietors.

(*a*) *Objectives*

It was particularly desired to do something constructive in the sparsely populated and depopulated county of Sutherland. The area selected was based on two main railheads, Lairg and Ardgay. The first-named is an important focal centre from which roads radiate to the north and north-west coasts. It could be developed as a key centre and railhead. It was hoped that, if the scheme was successful, operations could be extended outwards along these roads, which might help to

improve communications to the north and west coasts of Sutherland and to Wester Ross and so give a firm basis for development of the rather more populated but rapidly depopulating coastal crofting communities.

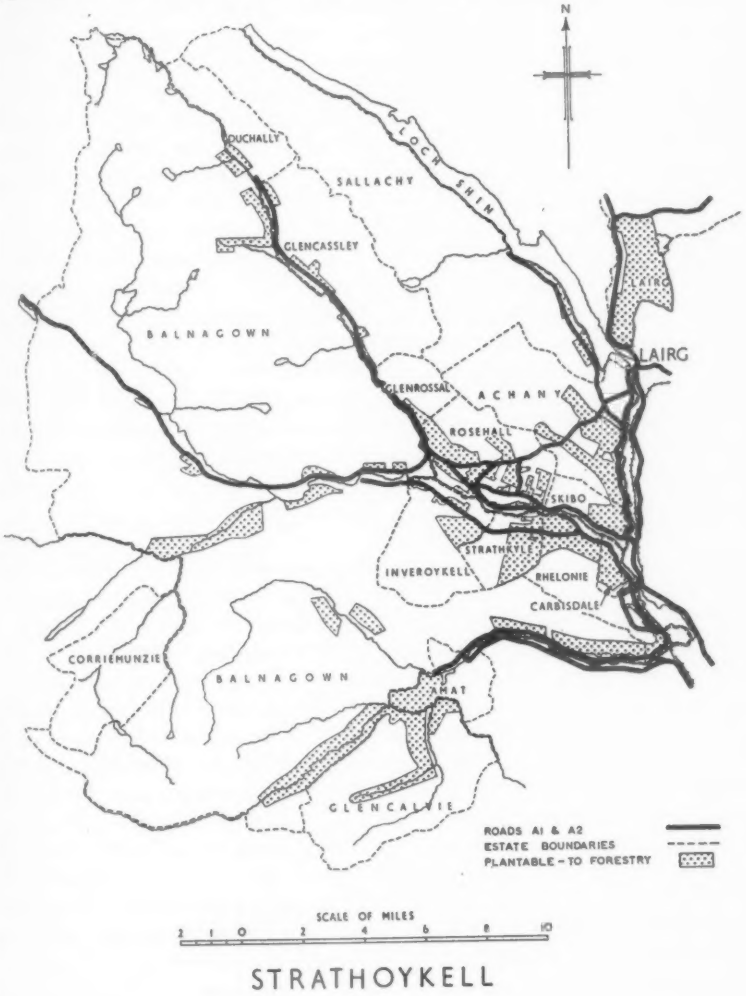


FIG. 1

The immediate object of the survey was to discover the possibilities of development of agriculture and forestry and to consider how such developments could best be planned in a unified scheme. The main possibilities for forestry were considered to be (1) the maintenance of effective production of existing plantations,

(2) replanting of felled areas, (3) replanting of derelict or scrub woodland areas, and (4) the planting of selected areas of bare ground. For agriculture the main possibilities for development were considered to lie in (1) the increase of cattle stocks by the creation of cattle-rearing units of various sizes, (2) the development and reorganization of sheep farms to create workable and economic units under modern conditions, (3) the improvement of grazing areas by planting of shelter belts, by surface regeneration, and other forms of land improvement, (4) reorganization and development of crofting townships, and (5) the creation of conditions making it more possible to retain shepherds and their families in the glens. The woodlands would eventually provide considerable employment and planned housing of the men and their families in suitable communities would benefit the whole area. In the more outlying areas, far up the glens, joint communities of shepherds and foresters would be likely to secure amenities that would otherwise be lacking; for example, good roads, electricity, and services of various kinds; this should help to retain the shepherd population which otherwise is drifting away, and a definite contribution would then be made towards the solution of one of the problems of the hill-farming industry. Those sons of shepherds who do not wish to follow their father's calling tend just now to move to the industrial south; work in the forests, in sawmills, more transportation in their home country might induce them to settle there, keeping their sons in turn interested in rural affairs and employment.

(*b*) *Survey results*

It was found that of the 250,000 acres examined, there were 2,000 acres of existing plantations, 7,000 acres of scrub or felled woodland, and 26,000 acres of bare land suitable for planting. After considering how best forestry might be fitted into the general agricultural pattern, always taking into account the fact that the aim was increased production from agriculture as well as from forestry, it was finally decided that the bulk of the felled woodland and scrub should be restored to productive forest, and that some 13,500 acres of bare land should be planted. So, with the 2,000 acres of standing timber to be brought under proper control, there would eventually be 22,500 acres of productive woodlands in the area. On the agricultural side, there should be an increase of 500 beef cows; a rough estimate at the time of the survey showed about 300 beef cows. Due to the abstraction of land for planting, the sheep stock of about 16,000 ewes might be reduced in the first instance by some 2,000 ewes, but it seemed probable that the increased shelter and the possibilities of grassland improvement in the neighbourhood of this shelter would eventually enable the sheep numbers to be restored. The woodlands would eventually provide employment for from 200 to 300 men, some in villages and some well up the glens as neighbours to the shepherds.

(*c*) *Development progress*

The attempt is being made to carry out the scheme on a voluntary basis and without calling on any financial aid additional to that already provided through the various schemes administered by the Department and the Forestry Com-

mission. The achievement of the objectives rests primarily with the owners and occupiers with whom there are consultations both in the survey stage and again when the question of actual acquisition of land arises. The Forestry Commission are ready to buy land for afforestation or to assist private planting under the Dedication Scheme.

On the forestry side, by the end of Forest Year 1957, 14,659 acres had been acquired or approved for acquisition and 7,374 acres of scrub and bare land of the 20,500 planned had been planted. Forty-seven men were employed by the Commission and there has been an increase in employment in nurseries outside the survey area. The Commission has built or reconstructed 13 houses for its workers. The county councils of Ross and Cromarty and Sutherland have also built, in two new villages, 34 houses which were intended for occupation by forestry workers, but at present, because of the shortage of labour for forestry and the comparatively high rents charged for the houses, the majority are let to other tenants. One of the major difficulties encountered in developing the scheme has been competition with contractors for the Hydroelectric Scheme at Loch Shin. Because everything is being carried out on a voluntary basis and every opportunity is given to all concerned for discussion, development is gradual but this is in some ways desirable so that the forestry work should be carried out in a way which would provide steady employment rather than a planting rate which could not be maintained. The change from agriculture to forestry takes place gradually and farmers have time to adjust the management of their grazings with as little disturbance as possible.

On the agricultural side the various grants and subsidies are available, including assistance for comprehensive schemes under the Hill Farming and Livestock Rearing Acts, 1946–56. Schemes in this category which have been submitted so far cover an area of approximately 150,000 acres and the works proposed are estimated to cost £95,000. Of the remaining 100,000 acres in the survey area a very large part is deer forest or high outlying land. There has been a drop of 500 in number of ewes but the total head of sheep has increased by 4,000. There has been a significant increase in the numbers of cattle carried; an increase of 500 beef cows had been forecast but already, with 7,000 out of 20,500 acres planted, there were 450 more beef cows in June 1957 than there were in June 1947, and the total head of cattle has risen from 850 to 1,500. Some part of this increase has been effected on Achany Farm which was part of the first acquisition by the Forestry Commission. The farm was taken over and managed for a period by the Department during which time the sheep stock was improved; where there had been no cattle there are fifty outwintering cows with the whole of the winter feed produced on the reclaimed arable land. Since Martinmas 1953 the North of Scotland College have rented the farm and continue to stimulate agriculture in the whole surrounding area by work on grassland improvement, comparison of home and away wintering of hogs, and a host of other trials and demonstrations visited by farmers and clubs from Caithness, Sutherland, and Ross.

In the statement of aims there was mentioned the reorganization and development of crofting townships. Before the appointment of the Crofters Commission

this was not possible; that body, coming into being in October 1955, is now active in the matter and endeavouring to secure the agreement of crofters in various crofting areas to planting, where beneficial, on common grazings.

(d) Summing up

This Strathoykell Scheme has shown that development does not take place rapidly but it holds out great hope that forestry can be integrated with agriculture in these hill areas without loss of stock-carrying capacity, indeed that cattle-raising possibilities may be enhanced; that the shepherd population can be retained in the glens; and that indeed the whole rural economy can be given fresh vigour.

FURTHER SURVEYS

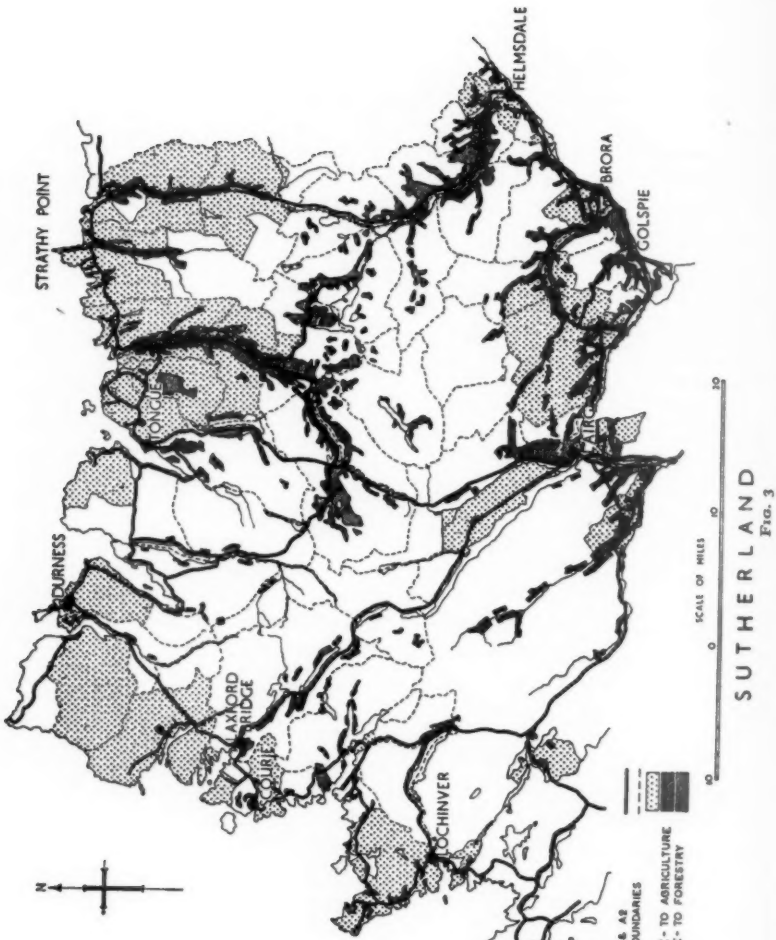
The Government White Paper Cmd. 7976 'Programme of Highland Development' (Scottish Home Department, 1950) stated that 'It is proposed to carry out a systematic survey to determine the best use of the land in each area of the Highlands and to follow up this survey as it proceeds by such action as is competent within existing powers to secure that the land is put to its best use'.

Before publication of the White Paper, further surveys had already been initiated, the objects in view being generally similar to those in Strathoykell. The area that has now been covered is over 3,000,000 acres and includes most of the county of Sutherland, the parishes of Gairloch and Loch Broom, the valley of the River Spey, half the island of Skye, almost the whole of the island of Mull, and the island of Jura (Fig. 2). The resulting information is of the greatest importance in planning the best use of land in the Highlands. There is not time to tell of the varying conditions and results in each of these areas mentioned but a glance at the map showing the results of the Sutherland survey is worth while (Fig. 3). This extensive county of fully 1¼ million acres, having only 14,400 inhabitants, has, with the exception of a small corner in the south-east, been all surveyed. There were found to be 7,000 acres of standing woods and roughly 100,000 acres of plantable land—felled woodland, scrub, and bare plantable. Of these, 55,000 have been recommended by the Department of Agriculture for planting, of which 11,000 are on crofting land. The parishes in the north and west are crofting parishes desperately in need of ancillary occupations now that inshore fishing has failed as one of the mainstays of the crofter fisherman. There is only a small amount of the land in these coastal parishes suitable for normal commercial planting. To help in the coastal crofting areas in the north and west generally, the Secretary of State announced in 1955 that during the next ten years the Forestry Commission had been authorized to plant in the crofting areas some 25,000 to 30,000 acres of land which would not normally be considered an economic proposition for forestry. Some 8,000 acres of land in this 'special planting' category have now been acquired in the crofting counties and almost 200 acres had been planted at the end of Forest Year 1957.

The total area so far surveyed in the seven crofting counties is 3 million acres, 360,000 acres have been deemed plantable and of this about 200,000 acres have

SUTHERLAND
ASSYNT
LAIRG
STRATH OYKELL
LOCH BROOM
WATERNISH
GAIRLOCH
APPLECROSS
GLENDALE
FORTREE
DUNVEGAN
GLENBRITTLE
STRATH
SLEAT
KNOYDART
INVERNESS
SPEY VALLEY
ABERDEEN
FORT WILLIAM
MULL
OBAN
JURA
GLASGOW
EDINBURGH
CAMPBELTOWN
SURVEY AREAS
MULL
BOUNDARY OF CROFTING COUNTIES
SCALE OF MILES
10 0 10 20 30 40 50 60 70 80 90 100
RURAL DEVELOPMENT SURVEY
SCOTLAND

FIG. 2



SUTHERLAND
FIG. 3

been cleared for forestry by the Department of Agriculture. The plantable area acquired or approved for acquisition since the surveys started is 38,000 acres.

Progress in development is slow. Owners and occupiers require time to consider such fundamental and permanent reallocation of land as is proposed. Relations remain friendly. No proprietor has refused the request issued by the Department of Agriculture for permission to include his land in an area to be surveyed. The Forestry Commission have not used their compulsory powers of acquisition in following up the surveys. Meantime, however, the Commission have profited by experiment and experience and are now planting peaty ground, previously considered unplantable and are pushing their planting line higher up the hillside. The Department of Agriculture have made available land on their estates on various soils in exposed sites in Caithness and Sutherland and the Commission have pilot plots there and at various points on the north-west coast. Antipathies to tree planting that existed in some areas are breaking down.

Two farms will play an important part in the furtherance of the integration of forestry and agriculture in the Highlands. The usefulness of Achany, the first acquisition in the Strathoykell area and now run as an experimental and demonstration centre for the northern counties, has already been mentioned. It will be some time before the full benefit of the plantations on the grazings will be felt. The second farm is Lephinmore, on Loch Fyne in Argyll, which in 1948 was made available for research and experimental work. The estate of which this farm forms a part was acquired by the Forestry Commission for planting. The agricultural unit is operated as a research station by the Hill Farming Research Organization and is a good locus for studying the problems arising from the extension of afforestation of hill land. The effects of the altered layout of the grazings on the value of the sheep are being studied and the change of environment resulting from the growing woodlands. The best utilization of the limited arable land is being studied, a system of intensive grass cultivation is in operation, devoted partly to conservation of winter feed for hill cattle and partly to provision of spring and autumn grazing to serve as a high protein complement to the grazing of the hill downfall which will be used for their summering.

FIG. 3

SHELTER ON UPLAND GRAZINGS

The Forestry Commission, provided they have a centre of operations in a locality, are purchasing much smaller blocks than formerly and shelter belts can play their part in the attainment of forestry objectives as well as in improving conditions for stock. But one of the greatest hindrances to rapid development of the plans in these survey areas is the lack of clear and demonstrable proof of the value of shelter, and well-founded directions on how best to obtain the shelter, whether by belts or blocks.

The value of shelter belts and windbreaks on agricultural land has long been recognized in this and in other countries. In Scotland it was recognized by the agricultural improvers of the eighteenth and nineteenth centuries when shelter belts were employed as one of the foundations of development of exposed and

marginal land. Other countries, such as Russia, Denmark, and America, have maintained their interest in the subject over a long period and have developed a scientific approach to the technique of planting woodland belts and narrow strips of trees for shelter against the storm. But in this country interest faded during the industrial age and it is only comparatively recently that the matter has come again to be recognized as one of importance. The Report of the Committee on Hill Sheep Farming in Scotland, 1944, and the Report of the Hill Lands (North of Scotland) Commission, 1956, both stress the value of shelter.

Establishment of shelter belts is one of the items eligible for grant in the Hill Farming and Livestock Rearing Land Improvement Scheme, and now also in the Farm Improvement Scheme. The provision of shelter belts is, therefore, now a recognized improvement on hill farms. The object of the rural development surveys is the proper integration of forestry with agriculture in such a way as not only to further the forestry programme but also to secure benefits for agriculture in various ways, including shelter. It would therefore seem desirable to ensure that as much sound guidance as possible should be available to all concerned.

Most of the countries in which research on shelter has been undertaken have been concerned with the improvement of agricultural plain areas. Much can be learned from their work that helps in fundamental research on forestry and meteorological aspects of the problem, but there is little scientific information regarding shelter-belt siting, construction, and value in hilly or undulating land; nor does there appear to be much dealing with animal welfare. To what extent does the provision of shelter affect food requirements and lambing and calving percentages?

The Agricultural Departments (1956, 1957) have issued leaflets giving advice on the establishment of shelter belts and the Forestry Commission has produced a pamphlet dealing with the particular problems encountered in Wales (Cadman, 1953). These leaflets enunciate general principles and provide some advice on shape, composition, and siting. Another publication, 'Shelter-belts and Microclimate' (Caborn, 1957), reviews, with bibliography, the available scientific evidence concerning the effects which belts of trees exert on the climate near the ground in the sheltered area, also their influence on agricultural yields and forestry practice. The author's field research on the influence of shelter belts concentrated on the assessment of the efficiency of a few selected belts in the vicinity of Edinburgh; these investigations were exploratory studies directed towards the determination of shelter-belt structures which are likely to afford maximum sheltering efficiency.

The planning of shelter belts is a complex matter. What is the most effective initial design—length, width, final height, and cross-sectional profile? What should be the structural composition—species, planting pattern, wind penetrability? How can the plantation be maintained for sheltering efficiency and continuity? These problems are intensified in our hill country where the topography results in local eddies causing changes in wind direction, and where there are possibilities of augmenting the natural shelter provided by local features. Siting

the shelter for most beneficial effect needs much consideration. Should it be on the ridge, on the windward slope where it may be most effective, or on the leeward slope where it is most easily established? Is the shelter desired occasional shelter in a storm or more permanent shelter of an area where there may also be improvement of the grazing? Is snow the problem? There are conflicting ideas as to the optimum penetrability for snow conditions and indeed for all conditions. These are only a few of the matters on which more definite guidance is necessary and some of them require further investigation by sylvicultural, agricultural, meteorological, and aerodynamic experts. Perhaps the most urgent requirement is more exact information on the benefit to animals and on the economics of shelter planting.

Local evidence and knowledge must be the final basis of site selection. This evidence can come from the landlord, the tenant, and the shepherd, the latter perhaps the most important with his intimate knowledge of his hirsel, and its dangers, his observation of vegetation and animal behaviour. His interest must be roused in any plan for he it is who will be best able to watch the development and guard against the continued neglect and gradual deterioration which have rendered ineffective many of our shelter belts. All interested parties—landlord, tenant, shepherd, and officials—require clearer and more specific advice than is now available.

The question arises as to whether it is desirable that there should be in Scotland a concerted attack by agriculturists and forestry experts with the help of meteorologists, to glean in the first place from existing knowledge what is applicable to this country, especially from the upland farmer's point of view. Between Edinburgh and the Border there are many plantations and shelter belts, a survey of which might meantime provide much practical guidance. There is no doubt that more land would be planted in all the areas surveyed if our knowledge of shelter value and provision were greater.

Another matter requiring investigation is the value of scrub on the hill as compared with plantations. Scrub provides shelter in winter and in summer. How quickly is it disappearing on our hills? Should efforts be made to preserve it?

CONCLUSION

The rural development survey idea can be of great value in planning a sound land-use policy particularly in hill and upland areas which make an important contribution to Scottish agricultural production. Hill and upland farms account for some 35 per cent. of the output of store and fat sheep and over 60 per cent. of the output of wool, while the total annual value of their agricultural output is now around £20 million. It has been shown how a much more satisfactory allocation between forestry and agriculture can be made if the canvas is large. There is need to make the fullest possible use of the land, to have a mixed economy, so that families of agricultural workers, especially shepherds, can settle in their home country, and there is need to provide employment in crofting areas. Improved amenities will be justified. Indeed in some areas in the north there can be little else than sound land use on which to build a county development plan.

Undoubtedly these surveys hold out new hope in our sparsely populated and difficult areas.

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FORESTRY IN NORTH SCOTLAND

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SUMMARY

History, climate, geology, and soils are dealt with in general terms and the history of land use from the seventeenth century in the seven crofting counties is discussed, while the problems of integration of forestry and agriculture are considered. The Forestry Commission forests in the North Conservancy are described. The forests are grouped into six different groups, the forests in each having certain common characteristics. Problems of physiography, geology, soils, species selection, silviculture, management, and utilization are dealt with for each group.

HISTORICAL

VERY little information is available concerning woodlands in the Highlands in early times. What little evidence there is points to the Highlands being colonized by birch (*Betula* spp.) following on the retreat of the ice some 12,000 years ago. This was followed, in the Boreal period, by birch/pine natural forest with dense hazel (*Corylus*) undergrowth. Later, in the sub-Boreal period, elm and oak appeared. Climatic changes, following the sub-Boreal period, erased considerable areas of Highland forest and replaced it with blanket bog which persists to this day in many parts of north Scotland.

By the Middle Ages, however, there were still large areas under trees, though almost certainly these were scattered and degenerate. It was not until the sixteenth century that we find, with the growth of estates and properties and mansion houses, the first deliberate attempt to establish and conserve woodlands in the form of policy woods. The earliest plantings were almost certainly for amenity; perhaps not till near the end of the seventeenth century do we find shelter-block planting, to provide shelter for stock and firewood for the home.

However, while these plantations were being formed, considerable inroads were being made into the natural woods in the straths and glens by the iron-smelters, by the shipbuilders, and by the housebuilders.

In 1607 a 'bloomery' was set up at Loch Maree. A 'bloomery' was the first forge through which iron passed after it had been melted from the ore. To provide fuel for it large tracts of Highland natural forest were bought and devastated. Exploitation for this purpose continued until the middle of the nineteenth century. Amongst the areas of natural pine forest which were devastated during this period by the iron-smelters, the shipbuilders, and the housebuilders were Abernethy Forest, Rothiemurchus Forest, and Glenmore Forest on Speyside and the forests on Loch Maree side, in Glengarry and in Glenmoriston. The exploitation of the natural hardwoods for charcoal lasted from about 1609 until 1788.

This record of destruction is incomplete without mention of the sheep farmers

who first appeared in the 1780's and who burned large areas of pinewood—to improve sheep pasture!

By the end of the eighteenth century it is clear that noteworthy efforts had been made to restore the damage. The First Statistical Account of Scotland (1792–6) devotes considerable space to the subject of woodland, as does the Second Statistical Account published in 1845. The prosperous estates in the middle of the last century laid down large areas in trees, until the agricultural depression of the 1880's restricted their plans. Interesting examples of the effect

TABLE I. *North (Scotland) Conservancy. Age class distribution of high forest area as at September 1957. Private estates and Forestry Commission. Area in acres (thousands)*

Age class	*Private estates*	*Forestry commission*
1–10 . .	21·3	67·9
11–20 . .	5·0	13·4
21–30 . .	6·5	25·6
31–40 . .	6·0	8·8
41–60 . .	9·8	
61–80 . .	12·2	
80–120 . .	16·8	6·8
120+ . .	10·1	
Uneven . .	8·6	
Totals . .	96·3	122·5

of this check are still clearly evident in the Black Isle (Fig. 3) and at Torridon where the inadequate drainage of plantations laid down about 1900 compares very sadly with the intensive drainage of 50 years earlier (Fig. 4).

The two great wars of this century saw the virtual extinction of the older age trees in the Highlands. In the 1939–45 war it is estimated that 53,000 acres of Highland woodlands, yielding 122 million hoppus feet, were clear felled and it is proper to remind readers that nearly all this was grown on private estates. It is greatly to their credit that at the end of the war many of the large estates, particularly those with a long tradition of forestry, set about the task of replanting with such vigour that, together with the Forestry Commission's work, the picture of Highland woodland devastation has been very noticeably relieved already.

The area under forest as at September 1957 is given, by age class, in Table I.

To end this historical note mention must be made of such natural woodland as remains today. Natural woodland occurs in two distinct forms—as hardwood scrub and as remnants of the former large tracts of Scots pine (Fig. 2). The scrub is mostly found in remote parts or on inaccessible steep slopes and is composed of birch, rowan, and in a few places oak. The remnants of old Caledonian pine forests are to be seen at Strathoykell, Achnashellach near Lochcarron, Loch Maree, Rhidorroch, Shieldaig, Glen Affric, Glengarry, Glenloy, Strathspey, Glenmore, and Rothiemurchus. These remnants vary in age but in the main they are from 150–250 years of age. Considerable quantities of the older trees are badly infected with

Trametes pini. Although every effort is made by the Forestry Commission to collect cones from the old Caledonian pine stands, the quantity available is extremely small. There is little doubt, however, that the trees in the younger plantations on Seafield estate in Strathspey are the progeny of old Caledonian pine trees.

SOCIOLOGY

No informed claim has ever been made that forestry in itself will reverse the continuing trend of Highland depopulation. It cannot be denied, however, that the planting of large areas in the north has established, in modern conditions, communities in places where communal life was thought to have vanished for ever. There has, too, been a very natural increase in the number of persons employed in the industry.

In 1881 (Collier, 1953) the number employed in the Highlands on forestry was fewer than 350 foresters and labourers, with some casual employment of crofters. Just before the last war private estates employed 300 men and the Commission 650.

A conservative estimate today is that the private estates now employ 400 men on forestry. The Commission employs 1,100. In addition a fair number of contractors find work in forestry operations. The timber trade at any given moment has a few hundred engaged on utilization work, and haulage contractors and British Transport have a lively interest in this field.

Forestry offers, and will long continue to offer, supporting employment to a large number of crofters. Some further reference to this aspect will be found under the section entitled 'Land Use'.

GEOLOGY

Dating from pre-Cambrian times the basal rocks of the area north-west of the Caledonian Canal were Lewisian gneisses so called because of their widespread occurrence in the Island of Lewis, though they form also the basal rocks of western Sutherland and Ross (Stamp, 1946). Included in the Lewisian gneiss are intrusions of granite and pegmatite. The gneisses were intensely folded and metamorphosed still in pre-Cambrian times and on their denuded surface was laid down Torridonian red sandstones. These latter are easily discernible because of their well-marked vertical jointing and are noted for their spectacular cliff scenery. Stac Polly in Wester Ross is a well-known example. On the Torridonian sandstones were laid down Cambrian strata which include the Durness limestone. Towards the end of the Silurian period and into the Devonian period the great Caledonian earth movements determined the major structure of the Highlands with a typical north-east–south-west trend. A huge mass of metamorphic schists slid westwards over the existing surface, creating a sandwich of Cambrian sediments between a lower layer of Archaen gneiss and Torridonian sandstone and an upper layer of Moine schists.

These earth movements gave rise to the geological phenomenon known as the Moine-Thrust, the plane of which stretched in a line from the tip of Ardnamurchan

to a little to the east of Durness. The line roughly follows the present watershed. Following on the uplift, torrential streams from the newly elevated mountain range dissected the plateau vigorously. Great thickness of coarse conglomerate and sandstones known as Old Red sandstone were deposited on top of the ancient gneisses in Caithness and the east coast of Sutherland and Ross-shire including the Black Isle. Frequently these Old Red sandstones were covered with boulder clay of varying thicknesses.

It is probable that the Grampians date from the time of the Caledonian earth movements. Today the Grampians consist of an elevated peneplane about 2,000–3,000 feet high. The Grampians are of granite but underneath are probably of very complex structure (Stamp, 1946).

In Tertiary times the basaltic lavas and intrusions of Skye, Mull, and Morvern were laid down on Moine schists. The igneous geology of the west coast is extremely complex.

The Great Glen is a rift valley, the faulting being especially marked on the north side.

Today the following geological formations can be distinguished:

1. Along the west coast the oldest rocks of Lewisian gneiss are overlain with Torridonian sandstone.
2. A narrow belt running north-east to south-west of Cambrian sediments of which quartzite is a conspicuous feature.
3. A large area of pre-Cambrian Moine schists.
4. An area of Old Red sandstone along the east coast covering Caithness and the Cromarty Moray Firth districts.
5. Areas of Tertiary lavas mainly basaltic in Mull, Morven, and Skye.
6. Scattered areas of granite in Skye, Mull, Morven, Strontian, Lochaber, in Eastern Ross-shire, Eastern Sutherland and in the Grampians.

Other formations which occur less commonly but which have an appreciable influence on the soil qualities are:

1. Cambrian limestone in small strips at Durness, Loch Assynt, and Lochaber.
2. Hornblende near Tongue, Altnaharra, Gairloch, and Ardgour.
3. Gabbro in Skye, Ardnamurchan, and Mull.

SOILS

The Lewisian gneiss produces a very poor type of soil but erosion has removed much of it, leaving extensive areas of bare rock. The topography of the country is such, too, that only small pockets of soil exist and these, too often, are incapable of being drained. The Torridonian sandstone soils are of a similarly poor type, but they can be improved by the addition of nutrients to support tree growth.

Within the mountain area the high rainfall and humidity produce peat as the main soil cover, lying thin on the highly polished quartzite surface of the Cambrian belt. The soils on the vast areas of metamorphic schist are variable but usually of a moderate to poor type. Frequently the soils are shallow but there are

numerous long, deep slopes which are ideal for forestry because of their free drainage.

Old Red sandstone provides soils of a rich character—light but of good agricultural quality. Glaciation has left these soils shallow on the steeper slopes but lower down they exist as deep rich loams.

The soil derived from the basalt lavas is potentially the richest in the Highlands. The rock is porous and weathers easily but this virtue creates a difficulty for foresters, since spring droughts on the porous rock cause numerous deaths and phosphorus tends to become unavailable as apatite.

Granites form soils rich in basic minerals. This is particularly noticeable on hillsides with free drainage of the flush waters.

Any consideration of soil in the Highlands must take note of the effects of glaciation. The ice-field in the Western Highlands was estimated (Pearsall, 1950) to be 4,000 feet thick. The massive ice-sheets in their movement scoured away existing soils, deepened existing valleys, and polished rock surfaces. Some areas, notably in Sutherland, were denuded of soil. Vast quantities of boulders and detritus were deposited and drift covered large tracts of land. This drift usually consists of boulder clay which forms a cement-like layer often impervious to water. The soil quality is largely determined by the depth of soil above the drift layer and by the thickness of the latter. It would appear to be safe to say that the forester's geological problems are those of the nature and distribution of the fluvio-glacial deposits. Drift *per se* may be a poor subject but one has only to consider those areas of old rocks—Lewisian gneiss and Torridonian sandstone—with no glacial drift, to realize its importance and value in successful forestry. In Commission-owned forests by far the larger proportion of the soils have a depth of less than 12 inches.

Where drainage is inadequate, peat inevitably predominates. Depth of peat and type of peat varies with slope and rainfall. Something like 1¼ million acres in the Highlands—about 13 per cent. of the land surface—is covered with peat more than 2 feet deep and depths of 20 feet are far from uncommon (Collier, 1953).

CLIMATE

The influence of climate is almost certainly no less important than the nature of the parent rock in determining the main characteristics of soil. The climate of the Scottish Highlands is essentially maritime with the prevailing winds from the south-west. The main mountain mass lies along the western seaboard and only a few miles inland. When the moisture-laden west winds strike this mountain barrier, precipitation, which increases greatly with elevation and diminishes in the direction of the rain-bearing wind, is at its most intense on the inland side of the mountains, often as high as 80–100 inches per annum. On the west side of the watershed it may fall to 60 inches, with a gradual diminution eastward; the Black Isle on the east coast normally receives less than 25 inches annually. The highest rainfall areas are at Glenquoich, west of Invergarry, Glencarron lying to the south of the Dingwall–Strome road, and the Onich district, south of Fort William.

The frequency of rain is also of great importance. Despite the heavy annual rainfall, the west often suffers from spring droughts, with cold, drying east winds, in the months of April and May and this lack of rain in spring on the porous basalt soils in parts of the west coast is often a factor limiting growth. In the west April, May, and June are the driest months, in the east autumn is generally very dry.

The Gulf Stream, passing northward up the coast, has a strong influence on the West Highland climate. West coast winters are traditionally mild and free from frost and snow while in the east the winter is usually marked by low temperatures, heavy snowfalls on high ground, and frequent late spring frosts which do considerable damage to the susceptible tree species.

Wind is an important factor affecting tree growth. On the west coast and more especially in the north and north-west exposure is a far greater limiting factor to tree growth than soil type. Strong winds and gales are of common occurrence in the north and west, but of less importance farther inland.

The comparative lack of sunshine—only an average of 3 hours per day over the whole year—and the high rainfall and humidity result in an abundance of surface water and large areas of bog. Bog formation can be expected when the rainfall is more than three times greater than the evaporation rate. The evaporation rate is fairly constant at about 17 inches and an annual rainfall of 50 inches is sufficient to produce bog formation.

The influence of high rainfall is exerted in another manner. The wet climate causes leaching of the surface layers and consequent building up of an acid humus.

LAND USE

The three main uses to which land is put in the Highlands are (1) hill farming, (2) crofting, and (3) forestry.

True, there are some large arable farms in Easter Ross, East Sutherland, and Caithness, but the total acreage involved is comparatively small. There are also some deer forests still in existence but almost all now have some sheep on them.

Historically the three main uses are interrelated. Man broke into the primeval Caledonian Forest in the first and second centuries A.D. and, though the pattern and emphasis of land husbandry has changed and varied through the years, a fairly stable economy had been achieved by the end of the seventeenth century. Cattle were raised in the coastal belt and grazed in the glens. After the 1745 rebellion and the consequent destruction of the clan system the infamous Highland Clearances were initiated. Forests were destroyed to make room for sheep, and flockmasters from the south paid high rents for such land, caring not that as a result an ancient way of life was being disrupted as the native crofters were compelled, often by force, to emigrate or to move to the barren coast, there to wrestle vainly against circumstance and nature for a meagre living.

In the early years of the eighteenth century the sheep-cattle ratio was unity (Fraser Darling, 1955), today sheep outnumber cattle by ten to one (Collier, 1953). The newly cleared ground was overstocked with sheep; cattle stocking was severely cut and the absence of tree shelter increased the rate of soil deterioration.

Today most of the land has become marginal and upon this marginal land the hill-farming industry of the Highlands exists.

It is true and only fair to say that other factors have contributed to this condition. The soil is often poor and thin and frequently the land lies at considerable altitude. The weather has already been mentioned. There are communication difficulties and remoteness from markets imposes several disadvantages.

Nevertheless it remains clear that an artificial and unstable ecology has been introduced with the original destruction of the woodland vegetation and the repeated (and often unwise) burnings which go with sheep farming. The fertility has fallen and leaching continues to impoverish the soil. There are many moors which can now only support a few sheep. Hill farming in the Highlands is often markedly marginal in the economic as well as in the physical sense. Soil qualities make the ground suitable only for sheep (and even then they have to be fattened on lowland farms) and although the very considerable amount of hill drainage carried out since 1945 has undoubtedly improved the ground, there are still large areas where even the most uneconomic restitutional work would not succeed in restoring the land to its former agricultural value—and this is where, in our opinion, a very proper place exists for forestry.

The area of Highlands is reckoned at 9 million acres which represents 47 per cent. of the land surface area of Scotland; yet within that 9 million acres we find only 7½ per cent. of the cultivated area of Scotland (Collier, 1953). The cultivated area lies largely in the Eastern Highlands in large arable farms and partly in the main hill-farming area in the Central Highlands. The crofting areas are mainly in the north and west coastal belt.

Much has already been written on the history of crofting and its place in the economy of the Highlands. The Report of the Royal Commission of 1884 defined a crofter as 'a small tenant of the land with or without a lease who finds in the cultivation and produce of his holding a material portion of his occupation, earnings and sustenance and who pays rent to the proprietor'.

The Crofters Holdings Act of 1886, which followed the Report, defined a crofter as 'a person who dwelt within a parish in which there existed, or had existed, rights of common grazing and who paid a rent of less than £30 (later raised to £50) for his holding'.

Under various Acts a crofter (Report on the Crofting Conditions, 1954) has acquired certain cardinal rights:

1. Subject to his compliance with certain statutory conditions he could not be evicted from his holdings.
2. He could ask the Land Court to fix a fair rent for his holding.
3. On renunciation of his holding or removal from it, he could recover from the landlord compensation for permanent improvements.

The crofting picture has, of course, changed considerably since these days. In 1881 the population in the crofter parishes within the seven crofting counties (Argyll, Inverness, Ross and Cromarty, Sutherland, Caithness, Orkney, and Zetland) was 180,000. According to Collier (1953) it is now 130,000, of which 80,000 live on the islands and 50,000 on the mainland. Of the 2 million acres of

crofting land spread over 23,209 crofts in 1947 (Report on Crofting Conditions) only about 150,000 are in cultivation and most of these are on the west and north coasts where the soil is poor, shallow, acid, and wet. A certain amount of reclamation and improvement work is always going on but the various Government Grant Schemes, though praiseworthy, cannot hope to achieve a large-scale metamorphosis.

Many reasons have been adduced to explain the decline in crofting—and almost as many schemes to arrest it—but the broad comprehensive reason is simply that the bleak unrewarding struggle with Nature to earn a below subsistence level of living no longer commends itself in an age where ever-increasing prosperity and good living apparently marches comfortably, in the populated and industrial areas, with a corresponding reduction in the degree of effort and hours of effort required to achieve it.

This decline manifests itself most vividly in population incidence and we find that whereas the national ratio of people to acres is 1:1, the figure for the Highlands is 1:30. Perhaps even more disturbing is the fact that in the crofting parishes the number of people over 65 years of age has increased, during the last 70 years by 36 per cent.

The Crofters (Scotland) Act, 1955, resulted in the creation in that year of the Crofters Commission with headquarters in Inverness. The Commission was charged with the responsibility for reorganizing, developing, and regulating crofting in the seven crofting counties and of promoting the interest of the crofters.

Recognizing that forestry is a main potential ancillary employment for crofters, the Secretary of State for Scotland simultaneously authorized the Forestry Commission to acquire and plant 25,000 to 35,000 acres in 10 years under a scheme known as 'The Special Planting Scheme'. It was accepted that this land would almost certainly yield a lower than commercially acceptable annual increment but the gain in providing additional work for crofters was held to offset that.

Progress in acquiring land for this scheme has, however, been singularly slow and for the following reasons:

1. Crofts and hill farms are run mainly on the landlord–tenant system which militates against the break up of hill farms or crofting common grazings.

2. The hitherto accepted policy—a policy of all-round economy in forestry—of the Forestry Commission was to acquire as large blocks of land as possible. Not unnaturally, the hill farmers and crofters were reluctant to give up large areas which would reduce sheep stocks considerably. Current Forestry Commission policy accepts smaller blocks of land and the need for greater integration of forestry and agriculture which should at least maintain sheep stocks at their present level and would probably increase them if the remaining hill ground was improved.

3. Crofting is mostly on poor, exposed shallow soil with frequently very little plantable land outwith what was once the cultivated area of the croft. The choice is often therefore not agriculture and forestry but agriculture or forestry. There are still a number of crofting communities with sizeable holdings of well managed,

good quality land where the population is not predominantly middle-aged or old. These communities are prosperous and do not require the financial help of ancillary employment such as forestry. In most communities, however, the population is well on in years and could not accept employment in forestry. The abstraction of land for forestry in their opinion means a reduction in their sheep stock and income without any compensating factors. In these circumstances it is understandable that crofters are unwilling to give up land for forestry.

TABLE II. *North (Scotland) Conservancy. Total woodland area and area under high forest, privately owned and state owned in 1947. Area in acres*

County	*Privately owned (acres)*	*State owned (acres)*	*Total area (acres)*	*% land area*
	Total Woodland Area			
Caithness	1,921	..	1,921	0·4
Sutherland	26,873	4,087	30,960	2·4
Ross and Cromarty	70,837	25,036	95,873	6·1
Inverness	177,738	34,878	212,616	7·9
Nairn	18,473	1,556	20,029	19·1
North Argyll	16,208	8,505	24,713	4·6
Total	312,050	74,062	386,112	5·8
	High Forest			
Caithness	698	..	698	..
Sutherland	7,184	1,717	8,901	..
Ross and Cromarty	17,730	17,593	35,323	..
Inverness	42,574	26,546	69,120	
Nairn	6,607	462	7,069	..
North Argyll	1,916	7,191	9,107	..
Total	76,709	53,509	130,218	..

4. Estate owners are naturally reluctant to give up to forestry any of the small amount of plantable land remaining to them outwith the crofters' common grazings. Frequently this land is birch covered and provides useful shelter in exposed country for stock.

The White Paper on post-war forestry (Forestry Commissioners, 1943) envisaged 5 million acres of managed forest in Britain. It is inevitable that a considerable part of the 5 million acres should come from the Scottish Highlands: certainly far more than the 400,000 acres of productive and non-productive woodland in being in 1947 (Census of Woodlands, 1952). Table II gives the figures by county of the total woodland area and the area under high forest.

There is little doubt that all potentially afforestable land is used to a greater or lesser extent by agricultural occupiers, but equally the rough grazings provide the only possibility of completing the planting programme. Whether land should

grow trees or rear sheep is a subject of much debate. Where, however, areas have become submarginal for agricultural purposes trees could in all probability be profitably grown. Lessons learned from research over the past 30 years and improved techniques mean that many acres, formerly reckoned as unplantable, can now be planted with reasonable prospects of success. Vast areas in the Highlands are still, nevertheless, unplantable even by present-day standards.

Very substantial areas of even low-grade plantable land are subject to some form of grazing rights. Even when these rights are little exercised there always appears to be considerable opposition to a change of use. Greater integration of forestry and agriculture to produce the highest common factor has become accepted practice in the Highlands. Numerous examples can be found of forest blocks of 200–300 acres with 'down comes' for sheep often half a mile wide between the blocks. These blocks are sited and their boundaries fixed so as to give the maximum benefit to the sheep farmer. In crofting areas, however, where the plantable land available is considerably smaller, it is clear that the Commission will have to accept smaller blocks, often far less than 100 acres in extent.

In an area which is marked by its complete lack of industrialization forestry offers employment to comparatively large numbers of men in small remote communities which might otherwise cease to exist as such. In many places forestry is the sole employer, in others it provides ancillary employment to crofters. It has never been authoritatively claimed that forestry will reverse the depopulation trend in the Highlands, but it can be claimed in all honesty that forestry in the places in which it is practised has halted the drift to the south.

FORESTRY COMMISSION FORESTS IN THE HIGHLANDS

There are sixty-eight forests in the North (Scotland) Conservancy. The area afforested and reafforested by the Commission amounted as at 30 September 1957 to approximately 114,500 acres of which 46,500 acres were planted before 1946 and 68,000 acres since then. A further 8,000 acres of plantations have been acquired making a total of 122,500 acres under forest. Approximately 50,000 acres are provisionally earmarked for planting but much lies in areas where labour is short. The Conservancy has about 200 acres of nursery, mostly in the Black Isle, and is self-supporting for plants. The balance of the 468,000 acres owned by the Commission is either unplantable (mostly over 1,000 feet contour) or is let under agricultural or grazing tenancies.

The forest land acquired pre-war was mostly in the west and it included a fair proportion of good quality forest land. In those early days the worship of volume production was widespread and a natural consequence was that high volume producers were favoured in the plantings. Douglas fir (*Pseudotsuga taxifolia*), Sitka spruce, and Norway spruce (*Picea sitchensis* and *P. abies*) were specially favoured, often beyond the safe planting limits. The war-time and post-war plantings are mainly on the east coast in the drier rainfall areas, in fact, largely in pine country and in general on relatively slow-growing pine country. Thinning is unlikely to start in these areas until the plantations are at least 28 years old. In the west coast in a hydrid larch (*Larix* × *eurolepis*) area at South Strome,

thinning was started at 11 years of age and four thinnings had been taken out by the time the stand was 19 years old. In general on the west coast thinning in Douglas fir starts about the 18th year and in Sitka spruce in the 22nd year.

FIG. 1. The distribution of Forestry Commission forests in the North (Scotland) Conservancy.

Total volume of timber extracted from Commission areas in 1957 was just over 2,000,000 hoppus feet, 1,375,000 hoppus feet from thinnings and 668,000 hoppus feet from clear fellings largely of windblown timber. The potential thinning yield is at present about 1,600,000 hoppus feet annually. Nearly half of the volume was sold standing to timber merchants and the balance was sold to timber merchants either at stump or in the length at roadside. Only one forest, viz. Culloden, is converting completely. It is probable that the forests in the Highlands are more variable in geology, soil, and climate and are more varied in their silvicultural,

management, and utilization problems than the forests in most other quarters in Britain and it would be impossible within the length of this article to deal with the full sixty-eight forests. The majority of the forests can be subdivided into groups each group having several common characteristics although by no means similar in all characteristics and it is proposed for the remainder of this article to deal with the common problems of each group. Several forests which do not fall reasonably into any group will of necessity have to be omitted.

UPLAND HEATH FORESTS

A. General Description

1. *Forests in group*

Zehetmayr (1954) defined the heathlands of the east as areas where the plant remains form a thin layer consisting of raw humus rather than the true humus which, being found in greater depth, constitutes peat. The formation of peat is largely dependent on rainfall, drainage, and temperatures.

There are twenty-two forests partially or wholly in this group all lying in the low rainfall area of the east coast and in the valley of the Findhorn and Spey. Details are given in Table III.

It should be noted that on most of the forests listed there are areas which do not fall within the definition of upland heath.

2. *Former utilization*

There is little doubt that most of the land was at one time or other covered by forest. Some of the areas, notably in the Black Isle, have not had a tree crop on them in the last 100 years whilst others, e.g. Boblainy and Battan, largely consist of areas felled in the 1939–45 war. Many areas were cleared of trees in the latter part of the nineteenth century and since then have been used for winter grazing of sheep brought from the high ground in the west of Scotland where they were summered.

3. *Physiography*

The range in elevation is from sea-level to about 1,400 feet. Slopes are relatively gentle except in one or two instances notably the south face of Kessock. Aspects vary but are mainly either northerly or southerly. The prevailing wind is from the south-west but tree life suffers fairly severely from cold drying winds which come from the east and north-east during the spring.

4. *Geology and soils*

Most of the forests are on Old Red sandstone. The soils originate from the wash material of the Old Red sandstone drift and are largely light and sandy. The wash is covered over the greater part of the area by a raw humus layer which varies in depth from 2–6 inches except in the bogs. The average depth is about 5 inches. The raw humus layer varies in depth according to location. It is shallow on top of disintegrating rock, and also where water has caused the removal of the wash. On the lower slopes the readvanced moraine has left deeper depositions of wash and consequently a deeper richer soil is found and quite frequently the

farms are located on this. On the higher slopes where the forests are usually found there is a leached layer about 6 inches deep between the raw humus layer and the drift layer. Between the leached layer and the drift there is often a hard iron pan which is non-continuous. Above the pan and below the leached layer is an enriched layer in which the roots spread freely.

TABLE III. *Forests of the Upland Heaths. Land utilization as at September 1957*

Forests	*County*	*Area of acquired plantations (acres)*	*Area planted by Forestry Commission (acres)*	*Area awaiting planting (acres)*	*Unplantable agricultural and other (acres)*	*Total (acres)*
Aigas	Inverness	13	542	379	659	1,593
Ardross	Ross and Cromarty	1,509	2,802	971	1,151	6,433
Assich	Nairn	4	796	304	222	1,326
Battan	Inverness	131	1,274	415	347	2,167
Boblainy	Inverness	..	2,438	152	100	2,690
Clach Liath	Ross and Cromarty	50	1,030	799	401	2,280
Craigphadrig	Inverness	48	155	..	8	211
Culloden	Inverness	221	2,141	32	53	2,447
Dornoch	Sutherland	1	929	485	1,429	2,844
Ferness	Nairn	13	1,005	9	511	1,538
Findon	Ross and Cromarty	..	2,244	11	112	2,367
Inshriach	Inverness	538	2,377	3,604	9,661	16,180
Kessock	Ross and Cromarty	101	1,079	181	305	1,666
Kilcoy	Ross and Cromarty	589	2,370	135	470	3,564
Laiken	Nairn	15	808	3	12	838
Millbuie	Ross and Cromarty	67	6,663	9	597	7,336
Morangie	Ross and Cromarty	105	4,748	968	1,741	7,562
Queens	Inverness	142	3,085	65	9,208	12,500
Strathdearn	Inverness	149	2,142	169	1,731	4,191
Strathmashie	Inverness	438	717	2,218	1,169	4,542
Strathnairn	Inverness	54	1,091	53	1,239	2,437
Urray	Ross and Cromarty	50	836	4	109	999

The limiting factor for tree growth is the depth of the raw humus layer and leached layer above the hard drift. Generally the deeper it is the better the soil.

Briefly the soils can be classified as follows:

(*a*) Where the raw humus layer is exceedingly thin on top of disintegrating sandstone or lying on top of the rock outcrops. This type is a poor tree subject.

(*b*) Where the surface soil is absent and on which large pebbles of the drift appear on the surface, i.e. no wash on top of the drift, e.g. Greycairn Wood, Millbuie, and Harriet's Wood, Dornoch. This type is one of the most sterile.

(*c*) The general type where there is a shallow layer of raw humus and underneath a leached layer lying on top of the drift. This type varies in quality according to the depth of the raw humus layer and the leached layer. This is the general type on which the Commission's forests lie.

The underlying rock at Strathdearn, Ferness, and part of Laiken is mostly granite and at Strathnairn, Inshriach, and Strathmashie it is undifferentiated schistose rock covered by

drift of an undifferentiated nature. In these forests, and more especially on the latter two, the drift is of a gravelly nature and quite frequently is not compacted as is the case on the Old Red sandstone areas.

5. *Vegetation*

The ruling types are varieties of heather (*Calluna vulgaris*) and heath (*Erica ginerea* and *E. tetralix*). In rich conditions grasses and herbs are plentiful in number and species. On the poor areas heather, lichen and *Scirpus* predominate. Scots pine scrub is plentiful.

The vegetation types are largely governed by the degree of drainage. Where drainage has been neglected since the removal of the tree crop many years ago the soil quality has deteriorated.

6. *Climate*

The rainfall is low—25–35 inches per annum. Extremes of temperature are rare. Gales are few but hard, cold, drying winds during March and April are trying to young plants. Frosts can be fairly severe especially at Inshriach.

B. Silviculture and Management

1. *Ground preparation*

An examination of two mature woods in the Black Isle (Fig. 4) shows today that foresters a hundred years ago fully appreciated the difficulty of growing trees on certain of the upland heaths found on the coastal belt. The intensive degree of hand drainage carried out indicated that not only were drains for water carrying essential but also that drainage for aeration was equally essential. In the first Commission plantings it is doubtful whether this was fully appreciated. The early plantings at Culloden, Craigphadrig, Kessock, parts of Dornoch and the acquired areas at Ardross and Inshriach were successful largely because soil conditions were better—in effect the readvanced moraines had left deeper depositions of wash. The plantations at Findon (Fig. 5) and parts of Dornoch were not very successful where the type of upland heath soil common to these parts was generally met—5 or 6 inches of a raw humus layer over 5–6 inches of a leached layer on top of compacted drift. It is difficult to ascertain the number of chains per acre of drains put into the 1927–30 plantings but indications are that it was around 3–4 chains per acre on normal soils. This it should be noted is not very different from the quantity now put in after ploughing. Our present-day figure is about 2½ chains per acre. From 1930 onwards the number of chains of drains per acre steadily increased, in fact the average set was 15 chains per acre and the need for mechanical breaking up of the soil became appreciated as of major importance. In the Black Isle soils, quick growth on the edges of the drains was most evident where drains were cut into the hard drift layer. Unfortunately on these soils it has been proved that the effects of the drain were confined to a narrow width (estimated at 2–3 feet) from the sides of the drain.

Ploughing on a big field scale was begun in 1937 and the history of ploughing is largely a story of attempts to increase the depth-cutting powers of the ploughs in order to bite into the drift layer lying normally about 12 inches below the surface. The first plough used was the Unitrac Major. This was followed by the Solotrac and later the Haddington—all Ransome's products each stronger than its predecessor. The Haddington was used extensively on the upland heath type until the early 1950's. The R.L.R. plough was briefly tried but was found to be too cumbersome on areas where sound roots 30 or 40 years old could still be dug up. The life of the double furrow Cuthbertson was relatively short, lasting from

about 1949 to 1952. Its main advantage lay in the fact that it was the strongest plough experienced to date but it was rather apt to ride on top of the drift layer. Thereafter came Blane's tine and more recently the Ross plough both doing the same type of subsoiling jobs, the latter being more or less unbreakable. The fault of the Blane's tine was that it was mounted on the Cuthbertson carriage which unfortunately was not designed to withstand the strains of subsoiling.

Practically all the forests in Table III were formed after ploughing became common practice. Parts of Culloden, Dornoch, Kessock, Inshriach, Queens, the whole of Craigphadrig and about half of Findon were formed before the ploughing era started but this represents a very small part of the whole. Ploughing was done in general at 5-foot spacing. The Cuthbertson double furrow ploughing was done at 10-foot spacing. Trials at other spacings were carried out with results which indicated that optimum results were obtained from 5-foot spacing or complete ploughing. It is noteworthy of the results of ploughing that the Scots pine scrub, spread widely over Commission areas, has come out of check and is putting on normal growth. The scrub was left on the areas for shelter and ploughing through it was done in the best manner possible.

By and large it has been the policy on the upland heath type of soil to plough wherever possible. In some areas slopes are too steep but there soils are always deeper and better and ploughing is not so essential. On the slightly deeper soils where the drift is not quite so impermeable, trees will grow without ploughing but growth is slow. Such areas are found at Ardross, Boblainy, Dornoch, Strathdearn, Strathnairn, Inshriach, and Laiken.

2. *Choice of species*

The species planted have varied little from those of the first plantings in 1926. The ruling species is Scots pine (*Pinus sylvestris*) and in this respect it must be remembered that ploughing has permitted the planting of land which at an earlier date was classified as unplantable. Scots pine may be planted over practically the whole range of soil conditions of the upland heath type. Generally, however, its use has been confined to the following range of vegetation types—*Calluna-Erica*-grasses, *Calluna-Vaccinium*, *Calluna-Scirpus-Molinia*, *Scirpus-Calluna*. The use of Scots pine on the latter two types was made possible by ploughing and the use of *Pinus contorta* on ploughed ground has been small as practically everywhere ploughing has exposed mineral soil.

The use of *P. contorta* has steadily decreased with ploughing. On the poor soils before ploughing started it was used to a limited extent at Findon and Dornoch, especially on areas of poor *Scirpus-Calluna* or on areas where water action or ice action had removed the surface wash. Relatively its use has been negligible and generally confined to a few small pockets of deeper peat.

Corsican pine (*Pinus nigra* var. *calabrica*) was used in some of the early plantings at Craigphadrig, Findon, and Kessock but fell out of use until recently when some small blocks have been planted. The high death rates not only at the time of planting but when well established tended to limit its use but, where used, it has been confined to the slightly better soils of the *Calluna-Vaccinium*-grass type.

The use of European larch (*Larix decidua*) has been confined to the richer *Calluna*-grassland types where herbs are plentiful, and degenerate birch scrubland where the soil is deep and drainage free. European larch has not been used extensively and where it has been used it has normally been mixed in with Scots pine, on the better soils in a three and one mixture, notably at Ardross and elsewhere in small groups where patches of better soil are found.

The chief use of Japanese larch (*Larix leptolepis*) has been in the formation of fire breaks. For reasonable growth its soil demands are roughly as for Scots pine.

The amount of Norway spruce used has been relatively small. It has been planted on deep mineral soils found in the valleys of streams and in a few alluvial flats. It has also been used on areas formerly covered by hardwood scrub.

In the light of evidence there is little doubt that too much Sitka spruce was planted in the past on the upland heath soils with a low rainfall. In the 1920–30 period Sitka spruce was regarded as a tree for poor flush conditions a belief which was encouraged by those foresters who preached volume production. Today Scots pine would replace Sitka to a large extent. Areas formerly very wet have become quite dry following on ploughing. Some very successful Sitka spruce has been grown on old croftland and on alluvial areas but at 30 years of age they are becoming dry and brittle. Sitka spruce has been planted with a variety of nurses, viz. Scots pine, Japanese larch, *Pinus contorta*, but generally the mixtures have been unsuccessful as the Sitka spruce has gone into check very quickly on the poor flushes. Frost has not improved the chances of Sitka spruce.

Douglas fir has not been used to any marked extent on the Black Isle although small areas have been planted annually. Elsewhere, notably at Culloden and Craigphadrig and Kessock, Douglas fir has been planted on soils, certainly not as good as the type in the Great Glen normally associated with Douglas fir, but nevertheless better than average. In selecting areas for Douglas fir the best success can be looked for on firm birch scrub land where there is a good depth of soil.

Tsuga heterophylla has been used for underplanting (Fig. 13) and has also been planted pure at Kessock with notable volume production but *Fomes annosus* is prevalent.

Broadleaved trees form little part of the forest crops. Efforts at planting hardwoods have largely failed and only a few scrubby trees remain. Reasonable quality hardwood can be found on small alluvial flats on the sheltered sides of streams.

3. *Planting*

The first Commission planting in this group was at Culloden in 1925. Progress in the early years was naturally slow. Of the 41,273 acres planted by the Forestry Commission by 1957, 29,500 acres were planted in the last 10 years. Development has been rapid since the war and this is in no small measure due to the advent of ploughing.

In the early years the normal method of planting was by screefing the vegetation and then notching in the plants. Turf planting of spruces was normal practice on wet ground. Until very recent times on ploughed land the plants were notched into the back side of the upturned furrow. Since tine ploughing became normal practice the plants are planted near the edge of the tine channel, if there is no danger of water accumulating in the furrow. Manure has since 1931 been applied to Sitka spruce planted on poor flushes. Manure has not, however, been applied to any other species except on an experimental scale.

4. *Growth of species planted*

Scots pine. Over 70 per cent. of the Forestry Commission's plantings on upland heaths are Scots pine. Scots pine has therefore been used on an extensive range of soils, and it is not surprising to find occasional areas of poor growth. Such areas are limited in extent and their slow growth can be attributed generally to the soil conditions.

At Findon and to a lesser extent at Dornoch and Inshriach it is noteworthy that results have been attained similar to these in the acquired plantations of about 50 years of age. The knolls and inclines where the soil is deeper and the drift layer lower have grown good Scots pine while in the flats and hollows where the drift is nearer the surface growth has

FIG. 2. Glen Affric Forest. Old Caledonian pine.

PLATE VII

FIG. 3. Kilcoy Forest, Black Isle. 60-year-old Scots pine growing on drain-sides on poor *Scirpus-Calluna* site. Trees between drains have disappeared.

PLATE VIII

Fig. 4. Kilcoy Forest, Black Isle. 90-year-old Scots pine. Trees are concentrated on sides of drains dug at 21-feet intervals.

Fig. 3. Kilcoy Forest, Black Isle. 60-year-old Scots pine growing on drain-sides on poor *Scirpus-Callluna* site. Trees between drains have disappeared.

PLATE IX

FIG. 5. Findon Forest, Black Isle. Poor growth of Scots pine, planted in 1928 on unploughed ground.

PLATE X

FIG. 6. Millbuie Forest, Black Isle. Good growth of Scots pine planted in 1938 on ploughed ground.

PLATE XI

FIG. 7. Inchnacardoch Forest. General view of Lon Mor.

FIG. 8. Strathy Forest. Four-year-old *Pinus contorta* on poor exposed peat. An area ploughed for planting in the background.

PLATE XII

FIG. 9. Port Clair Forest. Fastest-growing sample plot of *Abies grandis* in Britain. Planted in 1932.

PLATE XIII

FIG. 10. Fiunary Forest. Poor growth of Sitka spruce on unploughed basalt ground covered by vigorous bracken. Planted in 1949.

PLATE XIV

FIG. 11. Fiunary Forest. Good growth of Sitka spruce on ploughed basalt ground. Planted in 1949. In the background is the Island of Mull.

FIG. 12. South Laggan Forest. General view of forest illustrating afforestation on the steep slopes of the Great Glen.

PLATE XV

FIG. 13. Kessock Forest, Black Isle. 80-year-old Scots pine underplanted with *Tsuga heterophylla*. Planted 1931–3 and 1946–50.

PLATE XVI

been desperately slow with a number of complete failures which are however seldom extensive. Some of these have been ploughed up and replanted.

On the ploughed land results have in general been good (Fig. 6), but there are areas where the drift is on the surface notably in the Whitebog area of Millbuie which are very poor. Ploughing was done as well as it could be in those days. The Research Branch have recently laid down experiments on this area. Sub-soiling and manuring are being carried out but the soil is exceptionally sterile.

Growth of this species is sufficiently encouraging to permit us to anticipate a productive value of quality class II/III Scots pine, probably nearer quality class III.

Corsican pine. Growth in the early plantings of this species P 30 Findon, P 29 Kessock, P 27 Craigphadrig, and P 39 Millbuie has been comparable to Scots pine. The trees are of a rough quality. The Craigphadrig stand has suffered considerable windblow.

Pinus contorta. On the unploughed *Scirpus* heaths there is clear evidence that *Pinus contorta* has grown better than Scots pine and even then it is fair to say that the *Contorta* has not done too well. This may be due partly to the seed origin which appears largely to have been 'inland'. On average type soils height growth has been about 10 per cent. greater than for Scots pine. There is some evidence of windblow on the early ploughed furrows of P 38–P 40 Millbuie.

European larch. Because of careful selection of planting sites the European larch growth has been more than satisfactory. In mixture with Scots pine it has usually topped the pine. There are instances in acquired plantations for example, at Ardross, where larch has been planted on spruce ground with somewhat disastrous results.

Japanese larch. This species has grown exceptionally well on average type Scots pine ground but on the poorer soils where the raw humus layer is thin very poor growth with frequent deaths has resulted. On suitable sites its form has not been too wavy.

Norway spruce. In general growth has only been satisfactory on deep flush sites where heather is not dominant. Elsewhere mediocre results have been obtained. There is a very good block of Norway spruce at Millbuie P 38 planted in the bottom of the furrow on a small grassy flush.

Sitka spruce. From results there is no doubt that this species has been too widely used, especially on poor flushes. At Ardross on alluvial ground and at Findon on old damp run-out arable soil, results have been good but on the poor flushes with an admixture of heather, *Scirpus*, and some *Molinia*, the plants have generally checked. At Inshriach particularly, repeated frostings have reduced growth considerably until the trees got above the frost line. Intermixed with other species it has seldom been successful. The nurse species has grown while the spruce has not.

Douglas fir. For a low rainfall area there are some excellent stands of this species at Culloden, Craigphadrig, and Kessock although its form is somewhat rough in the latter instance. In all these cases soils are undoubtedly above normal for the upland heath type. They are deep and firm. On average Black Isle soil conditions Douglas fir was planted experimentally from 1942 onwards. Early growth was good but after 7 years growth fell away and the trees are yellow and heavily infected with *Adelges*. The odd tree which is in the lee of a scrub Scots pine has continued to grow reasonably well.

As is common with this species wind damage is all too frequent and the very fine stand in the P 1906 acquired area at Culloden has been largely destroyed.

5. *Beating up*

The original species planted have not been substantially altered by beating up except in the replacement of Sitka spruce with pines. In most of the post-war plantings on heaths

there have only been two beat ups of any consequence, viz. following the severe winter of 1947 and the dry summer of 1955. In the latter the death rate was not so severe in areas straight planted but reached high proportions on some ploughed areas.

6. Weeding

Whin and broom growth in certain local areas sometimes of considerable extent has proved difficult to control. The neglect of the war years necessitated a complete replacement in some small areas on the Black Isle. Birch has never been very much of a problem because there are so very few areas of this on the heaths.

7. Thinning

(*a*) *Acquired woods.* As can be seen from Table III substantial areas of woodland were acquired. Most of these were Scots pine or Scots pine with a few European larch mixed through. There were, however, some areas of Douglas fir principally at Culloden which today are just over 50 years old. Apart from Ardross most of these plantations now fall into the 60 to 80–90 year age group. Ardross plantations are somewhat younger, being mostly 30–40 years old. These woods when acquired were little different from most of the other woods planted in the latter part of the nineteenth century—planted and left with no beating up, no cleaning, and no thinning. In general it is fair to say that the older woods have done quite well as, probably, the better sites were selected and with the abundance of money and labour available good ground preparation was carried out. With the lack of money thereafter, except where the ground was very good, the plantations are very patchy with good areas on the knolls and failures in the flats and hollows. The ravages of red squirrels of which there was a super-abundance as late as 1944 have contributed in no small way to malformed crowns. Snow in forests, such as Ardross, has done on occasion quite a lot of further damage.

Volume production has been variable due to the uneven stocking. In the 90 year old Bellton Wood in the Black Isle where the crop is reasonably uniform despite windblow in recent years, the volume is estimated at 3,800 hoppus feet per acre. This wood was intensively drained before planting and in consequence the volume gives an indication, with better management, of the potential one might expect on ploughed land. This wood was not thinned prior to acquisition and in the last 14 years between thinnings and windblow just under 2,000 hoppus feet per acre have been removed.

The younger woods at Ardross which were mostly planted at 3 feet spacing have now after two thinnings the appearance of first-class plantations and quite large areas lie in quality class II.

The acquired Douglas fir at Culloden was, until severely damaged in the 1953 gale and subsequent gales, a remarkably good stand for a low-rainfall area with moderate soil conditions. The volume production to 1957 was over 9,500 hoppus feet per acre.

All acquired woods have by consecutive thinnings been brought into shape. These thinnings were frequently at short intervals of 3 years but now the plantations are in shape the thinning cycle is 5 years generally.

(*b*) *Commission planted plantations.* Normally Scots pine plantations are not thinned until they are about 28 years of age. Small areas of other species, e.g. Japanese larch, have been thinned when only 16 years of age but this is more in the nature of a cleaning as the volume production from the thinnings only amounted to 100 hoppus feet per acre of utilizable timber.

Thinning has been carried out consistently in the early plantings since about 1950. The thinning yield has not been high averaging 200–250 hoppus feet per acre Scots pine,

and about 400 hoppus feet in the Douglas fir plantations at Culloden, Craigphadrig and Kessock. Thinnings have, however, in general been carried out at 3-yearly intervals in both Scots pine and Douglas fir for the first two thinnings. It has proved difficult to get a uniform breaking up of the Scots pine canopy in one thinning largely on account of the considerable number of wolves which had to be removed in the first thinning, and the policy has been to thin reasonably lightly in quick succession to get uniform distribution. After two thinnings the cycle is then 5 or 6 years. The thinning grade has usually been C/D grade low thinning but where necessary crown thinning has also been applied.

8. *Utilization*

In this group with one exception the policy has been to sell standing as much as possible of the thinnings and failing this, or where there is a necessity to keep labour employed, sell in the length at roadside and occasionally at stump. Until recently there has been no difficulty in implementing this policy. The annual volume production is around a quarter million hoppus feet.

The one exception is at Culloden where full production to the finished article is carried out. A twin bench sawmill is operated here to provide the bulk of the Conservancy's fencing demands and demands for timber for sheds, offices, &c., which are met from the fully equipped joiners' workshops. Buildings are made in sections and shipped out. In addition the mill has produced railway sleepers, wagon bottoms, and sawn mining timber. Production averages fully 1,000 hoppus feet output per week which is reasonable considering that numerous droppers and small orders of odd sizes have to be met. The mill is not entirely supported by Culloden. Sawlogs are taken in from surrounding forests especially timber for special purposes, e.g. bridging. The tops of the trees ex Culloden thinnings are converted to pit props.

It is of interest to note that so far six houses, four at Inshriach and two at Culloden have been built entirely of home produced wood ex Culloden sawmill and workshops with the exception of the shingles used for the roof and outside walls. In general the partitions were of Douglas fir and the remainder Scots pine.

FORESTS AKIN TO BUT OMITTED FROM UPLAND HEATHS

Six forests with a number of characteristics similar to those of the Upland Heath forests have been omitted from this group. They are Achnasheen, Glen Affric, Guisachan, Longart, Strathconon, and Torrachilty. These forests lie in the region of intermediate rainfall and while some areas have a very good soil there is a tendency for peat formation on the western ends of the forests.

The most interesting of these forests are Glen Affric and Guisachan where there are very extensive areas of Old Caledonian pine often intermixed with birch, particularly on north-facing slopes. In these forests there are considerable areas of good soil especially on the steeper slopes and there are areas where the drift layer is not compacted—rather akin to the loose Spey gravels.

The soil at Torrachilty and Strathconon is variable in quality. These forests are often on fairly steep slopes and where the soil conditions are good. At Longart and Achnasheen soil conditions are more inclined to deeper *Scirpus* peat and are consequently poorer.

Area statements for these forests are contained in Table IV.

FORESTS OF STRATHOYKELL

A. General Description

In many respects the forests in this group have characteristics similar to those of the Upland Heath forests but this group has been kept a separate entity because Strathoykell

was the subject of the first Highland Survey carried out on the instruction of the Secretary of State for Scotland for the purposes of the proper allocation of land to agriculture and forestry. Most of the Highlands are now covered by similar surveys.

1. *Forests in group*

There are four forests in this group, viz. Balblair, Craigs, Oykel, and Shin. Details are given in Table V.

TABLE IV. *Forests akin to but omitted from the Upland Heaths. Land utilization as at September 1957*

Forest	*County*	*Area of acquired plantations (acres)*	*Area planted by Forestry Commission (acres)*	*Area remaining to plant (acres)*	*Unplantable agricultural and other (acres)*	*Total (acres)*
Achnasheen	Ross and Cromarty	16	235	363	140	754
Glen Affric	Inverness	1,540	2,355	5,015	44,344	53,254
Guisachan	Inverness	194	1,755	1,053	2,642	5,644
Longart	Ross and Cromarty	6	1,255	185	76	1,522
Strathconon	Ross and Cromarty	32	1,943	710	604	3,289
Torrachilty	Ross and Cromarty	2	1,422	724	5,793	7,941

TABLE V. *Forests of Strathoykell. Land utilization as at September 1957*

Forest	*County*	*Area of original plantations (acres)*	*Area planted by Forestry Commission (acres)*	*Area awaiting planting (acres)*	*Unplantable agricultural and other (acres)*	*Total (acres)*
Balblair	Ross and Cromarty and Sutherland	184	1,529	607	3,914	6,234
Craigs	Ross and Cromarty	76	1,309	524	113	2,022
Oykel	Sutherland	42	1,194	2,607	738	4,581
Shin	Sutherland	124	2,917	495	10,550	14,086

2. *Land utilization*

About half the land acquired by the Forestry Commission was formerly under woodland. The remaining half was utilized for sheep grazing and to a lesser extent cattle grazing. Strathoykell covers the catchment areas of the rivers Oykell and Carron in the counties of Ross and Cromarty and Sutherland. Its economy is largely based on sheep farming and in consequence has a rather small scattered population. There is no doubt that more trees are required to improve the rural economy of the district.

The survey was carried out in 1948 initially by the Forestry Commission. Of the 254,000 acres inspected it was found that there were 2,000 acres of existing plantations, 7,000 acres of scrub or felled woodland and 26,000 acres of bare land suitable for planting. Following on consideration of how best forestry and agricultural interests could be integrated it was finally decided that almost the whole of the scrub and felled woodland area could be devoted to forestry plus some 13,000 acres of the bare plantable land. It was envisaged that the loss

of this land would cause a temporary reduction of about 2,000 breeding ewes but it was hoped that by increased shelter and agricultural improvements this immediate drop in sheep stock numbers could be made good. In addition there should also be an increase of 500 breeding cows.

Table V shows that at 30 September 1957, 11,608 acres of plantable land had been acquired out of a total of 21,000 acres finally allocated to forestry, and of that figure 7,375 acres are now under tree crops. In addition the pending acquisition of Dalchork will bring in a further 4,000 acres to forestry. There are also tentative proposals which will probably result in a further 2,000 acres being acquired for forestry.

On the agricultural side within the survey area there have been eight comprehensive Hill Farming Schemes formally approved covering an area of 132,000 acres and a further four schemes are being considered covering an area of 54,000 acres.

The proposed utilization of the land at Dalchork is a very good example of the integration of agriculture and forestry. This estate covers 25,000 acres of which about 4,000 acres are plantable. Practically the whole of the plantable land has been allocated to forestry. The agricultural land and the unplantable is to be utilized for sheep farming by the Department of Agriculture. By a progressive improvement scheme on unplantable land which is married to the rate at which the plantable land is needed for forestry it is hoped to move the existing sheep stock of 600 breeding ewes from the plantable to the unplantable. The Forestry Commission has in addition agreed to plant various shelter blocks ranging in size from 50 acres to 200 acres located to the best advantage of the sheep interests.

It is interesting to note that there are a few remnants of the old Caledonian pine forest in the Glen Einig area of Oykel.

3. *Physiography*

The areas acquired lie largely in the valleys of the Rivers Carron and Oykell and their tributaries the Black Water and the Rivers Cassley and Shin. The valley floors ascend very gradually while the valley slopes are moderate to steep. The valleys are separated by fairly wide plateaux. The range of elevation is from sea-level to about 2,000 feet. Aspects are north and south and occasionally north-east or north-west and south-west or south-east. Exposure is generally moderate to severe especially on the upper limits.

4. *Geology and soils*

The area lies in the region of metamorphic rocks being largely undifferentiated gneisses and schists. Limestone is strongly represented in Ben More Assynt and this has no doubt influenced the drift in upper Strath Cassley. The whole area is intensively glaciated. The soils at Craigs Forest and areas at Balblair, Oykel, and Shin are akin to those found in the upland heaths except that rock outcrops are more frequent and there are frequent morainic knolls usually sterile with the drift layer near the surface. Peat occurs at the higher elevations and in some of the valley bottoms. The peat varies in depth but commonly on the plantable land it is around 12 inches deep over a gritty leached soil on hard drift.

5. *Vegetation*

The main types are those of the upland heaths with fairly frequent patches of weak bracken. On the deeper peats the vegetation is generally *Scirpus* with a little heather and in the flushes *Molinia* and *Sphagnum* mosses.

6. *Climate*

The area is climatically intermediate between east coast and west coast. The mean annual rainfall varies from about 30 inches at the easterly limit (Balblair) to about 50

inches at the westerly limit (Oykel). Snowfall can be heavy and quite severe frosts occur. The prevailing wind is south-westerly.

B. Silviculture and Management

1. *Ground preparation*

Apart from the Balblair Wood section of Balblair all areas planted were planted in the post-war era, in fact, from 1950 onwards. Very few of the areas have a better than moderate soil and consequently all ploughable areas have been ploughed with a tine on hard ground and single furrow Cuthbertson on the deeper peat. Small unploughable flushes have been mounded. Some areas more particularly on Shin which appeared to have a slightly better soil and be of a better vegetational type would now, in the light of evidence, have been better ploughed.

2. *Choice of species*

The selection of species for planting has varied only in some small respects from that of the upland heaths. There has of necessity been greater use made of *Pinus contorta* more especially on the poor *Scirpus*/heather/lichen peats of 12–18 inches depth which is a common type found in the higher rainfall areas at the west end of Oykel and Shin forests. The general practice on this type of soil is to use a mixture of *Pinus contorta* and Scots pine, a Scots pine being planted wherever mineral soil is turned up by the plough.

Greater use has also been made of Japanese larch. Pure blocks were somewhat unsuccessfully planted on unploughed heather/poor bracken vegetational types in the early plantings at Shin Forest. Similarly, as was common a number of years ago in this Conservancy, too much Sitka spruce was planted in the poor *Scirpus*/heather/*Molinia* flushes where today *Pinus contorta* is largely used in mixture with Scots pine or, in the *Molinia* patches, with Sitka spruce.

The trend today in the selection of species for planting and the land quality in the Strathoykell forests can best be illustrated by the fact that in 1957 60 per cent. of the plants used for planting was Scots pine, 30 per cent. *Pinus contorta*, 4½ per cent. Japanese larch, 2 per cent. European larch, 2 per cent. Sitka spruce, and 1½ per cent. of other species. By far the greater part of the land acquired is well below quality class III Scots pine land.

3. *Planting*

Balblair Wood (733 acres) was planted 1929–37. The remainder of the areas were planted from 1949 onwards. The planting programme has steadily increased and has averaged 1,000 acres per annum since 1954 which is the target set for Strathoykell.

Methods of planting and the application of manures have been similar to those of the upland heaths.

4. *Growth of species planted*

It is too early to pass much comment on the growth of the various species. In the post-war plantings growth has been slow, much slower than one anticipated probably because the early plantings were on thin shallow unploughed soil, and again it is probable that too much Japanese larch was used on this type of ground.

In the old Balblair plantings all the main species have grown fairly satisfactorily although by and large the main species are confined to Scots pine, European larch, and Japanese larch. The European larch is badly infected with *Fomes annosus*.

5. *Beating up*

On the thin shallow unploughed soils the death rate has been higher than average. Deaths in the Japanese larch have been replaced with Scots pine and occasionally *Pinus contorta*. Similarly, Sitka spruce deaths in the poor flushes have been made good with Scots pine or *P. contorta*. On the ploughed ground the death rate has been similar to that of the upland heaths.

6. *Weeding*

This has been virtually non-existent except in small areas of birch scrub at Shin.

7. *Thinning*

(*a*) *Acquired woods*. The acquired woodlands amounting to some 426 acres are all in the thinning stage but have been neglected in the past and have frequent malformed stems and underdeveloped crowns. Bringing these plantations into shape is proving a slow process. Most of them have now received two thinnings at a three-yearly interval. Fortunately being in the 40–60 year age class in the main it is still possible to hope for a reasonable crop. The species is practically entirely Scots pine.

(*b*) *Commission planted plantations*. The earlier plantings in Balblair Wood have been thinned twice whilst the younger plantings will have reached the thinning stage in the next two years. Thinning grades have owing to the slow growth been relatively light, yields being of the order of 200–300 hoppus feet per acre in each thinning.

8. *Utilization*

Small quantities of thinnings have been felled, extracted, and sold in the length at roadside by the Forestry Commission largely to keep squads employed during bad weather. The bulk of the thinnings have been sold standing to timber merchants.

FORESTS OF THE NORTH COAST

A. General Description

1. *Forests in group*

There are five forests in this group, viz. Borgie, Dunnet, Naver, Rumster, and Strathy. In the north-east corner there are also four research areas, viz. Watten, Skiall, Forse, which are independent plots on their own, and Strathy which is within the limits of Strathy Forest but which was planted ahead of the forest. These forests and research plots vary greatly in their soil characteristics ranging from deep peat to sand but they have one common feature, namely exposure allied to generally poor soils. Table VI gives details of areas.

2. *Land utilization*

All the land was used to a greater or lesser extent for sheep-grazing. There is no doubt that some of the areas were once wooded, carrying timber in the sheltered valleys and scrub elsewhere.

3. *Physiography*

All areas are either flat or have very gentle slopes. All except Naver are within a few miles of the sea. Caithness and East Sutherland is gently undulating country with extensive flats and is exceedingly windswept with little shelter in the form of hills and valleys and there are very few trees indeed. The poverty of soil conditions combined with exposure

make planting in this quarter of Scotland often hazardous, if not impossible. The range of elevation is from sea-level at Dunnet to 900 feet above sea-level at Naver, but the plantable land, owing to exposure, lies in all but sheltered flushes below the 500-foot contour. Aspects are mostly northerly but they vary somewhat.

4. *Geology and soils*

The underlying rock of Borgie is undifferentiated gneissose schists although the western end of the forest lies on Lewisian gneiss. Naver and Strathy lie on undifferentiated schists although there is a small area of granite intrusions at Naver. Dunnet and Rumster lie on Lower Old Red sandstone.

TABLE VI. *Forests of north coast. Land utilization as at September 1957*

Forest	*County*	*Area of acquired plantations (acres)*	*Area planted by Forestry Commission (acres)*	*Area awaiting planting (acres)*	*Unplantable agricultural and other (acres)*	*Total (acres)*
Borgie	Sutherland	..	1,290	23	1,393	2,706
Dunnet	Caithness	..	241	567	71	879
Naver	Sutherland	..	..	5,151	11,757	16,908
Rumster	Caithness	..	866	134	1,362	2,362
Strathy	Sutherland	..	214	107	483	804

At all forests except Dunnet and the research plots at Skiall and Forse, areas of pseudofibrous peat (Fraser, 1933) are intermingled with areas of heath. *Scirpus* peat is usually found on soils with a rainfall of over 50 inches. It varies in depth from about 15 inches to many feet and is found on slopes, usually gentle, and bogs and is usually waterlogged all the year round. This type occupies a broad band on the north-west and west side of the country. The heaths dominated by *Calluna vulgaris* are of the usual type—raw humus over a podzolized soil and on occasion a hard pan. Normally this type can commonly be recognized at a glance by the configuration of the ground which shows the presence of morainic knolls and the action of ice. In general the drier areas tend to be heaths while concave slopes, basins, and wetter sites form peat bogs.

The research areas at Skiall and Forse are generally on reasonable mineral soil while the character of the soil at Dunnet is fixed by blown sand, gleyed at lower levels.

Practically all these soils are difficult forestry subjects apart altogether from the problem of exposure.

5. *Vegetation*

On the peat bogs *Scirpus* predominates with heather and heath (*Calluna vulgaris* and *Erica tetralix*) occasional purple moor grass (*Molinia caerulea*) and cotton grasses (*Eriophorum angustifolium* and *E. vaginatum*). On the heaths *Calluna*, frequently *Scirpus* and lichen (*Cladonia*). Dunnet is mostly Marram grass with sedges and hypnaceous mosses. There is also a surprising abundance of *Primula scotica*.

6. *Climate*

Rainfall varies from 35 to 50 inches per annum. Winds are severe and those which do the damage to trees are from the north-west. The number of calm days in the north of Scotland is relatively small. One must accept the fact that the outside trees of any forest block

in Rumster, Dunnet, Strathy, and to a lesser extent Borgie, will be shaved down to ground level and that utilizable forest trees will start 2 or 3 chains from the outside. Snowfall may be heavy but frosts except in frost hollows are of little consequence.

B. Silviculture and Management

The problems encountered in the forests in this group are problems which have generally to be faced in the areas in which 'special planting' will take place. While foresters might be prepared to accept poor quality land for planting in sheltered places or good quality land in exposed places, poor soil and exposure found together so frequently in the north and north-west of Scotland must of necessity rule out large areas for planting. Extensive areas of Caithness, Sutherland, and Wester Ross are, however, marginal on both counts and for this reason the forests and research plots already established are of vital importance in providing information. The techniques adopted in these forests were based on the peat experimental work carried out at Fort Augustus from 1925 to 1951, a brief account of which has been given by J. A. B. MacDonald (1945).

There is evidence to show that one can have little hope of successful afforestation unless the ground will plough reasonably and it is also believed that a moderate slope for natural drainage is generally essential for success.

1. *Ground preparation*

All forests and research plots belong to the ploughing era except the original plantings at Borgie which were practically entirely destroyed by fire in 1942. Borgie plantings, therefore, also fall into the ploughing era, replanting having been started in 1943. Although many eminent foresters stated that with a reasonable amount of draining Borgie was plantable, results were more than disappointing. An assessment of the 1920–31 plantings carried out in 1932 showed that of the 1,071 acres planted only about 400 acres were likely to reach a productive state. The very measure of the anticipated failure serves to indicate that the prospects of growing trees on these poor soils without ploughing are very slim. In consequence every acre replanted at Borgie and planted elsewhere has been ploughed; initially by the Solotrac and later by the Haddington and Begg and today generally by the single furrow Cuthbertson on the deeper peats or the Ross tine plough on the heaths with, where necessary, Cuthbertson single furrow drains between the knolls. Hand draining on a considerable scale linking up the furrows has to be carried out. The pseudo-fibrous *Scirpus* peats are usually waterlogged all the year round with the water table close to the soil surface and in consequence ploughing is as deep as possible and at 5 foot intervals since the effect of the drain only extends 2–3 feet laterally. In this type of soil the deeper the ploughing the deeper the rooting medium because tree roots are for many years confined to the relatively shallow layer of peat above the level of the bottom of the plough drains. The peat below this remains waterlogged and roots penetrating into it quickly die out producing the well-known shaving brush type of root system with long lateral roots on the surface and no deep anchoring roots.

2. *Choice of species*

Although most species have been tried in the five forests, in the light of experience very few are suitable. By and large the only species which can withstand the exposure are Sitka spruce and *Pinus contorta* and to a lesser extent Mountain pine, although farther inland away from the salt-laden winds Scots pine can be used, whilst on the sands of Dunnet Corsican pine may be successful. Except in sheltered pockets of good soil Douglas fir, Norway spruce, and European larch have failed. Japanese larch has been used occasionally

but seldom very successfully. It is a well-established fact that Sitka spruce stands exposure better than any other species but unfortunately where the peat is very acid and also where heather is present it undergoes an extended period of check and there is no evidence yet that, although it can be brought out of check temporarily by manuring, it will ever make a timber crop. On the deeper peats we have been forced to the conclusion that Sitka spruce should be planted on the good *Molinia* flushes and *Pinus contorta* elsewhere although even on the poor *Scirpus* peats provided they are a reasonable distance from the sea wherever the mineral soil is turned up by the plough a Scots pine can be planted with every prospect of success. It has become standard practice to mix in Scots pine in this fashion however dilute the mixture. There are grave doubts about the wind firmness of *Pinus contorta* and it is advantageous to mix in other species wherever possible. It is seldom that Sitka spruce can be mixed intimately with *P. contorta* but so long as Sitka spruce is confined to the *Molinia* flushes, however small, an irregular mixture can be obtained.

In the choice of species on *Scirpus* peat one has to be forever alert to vegetational changes. More often than not if there is a trace of *Molinia* in the vegetation originally, the *Molinia* becomes abundant after ploughing especially with the manure application necessary to establish a tree crop on this type of soil. One must guard against planting Sitka spruce generally and see that it is confined only to the reasonable quality flushes because inevitably although the vegetation is quick to change following on ploughing, by the fifth to the seventh year after ploughing heather predominates and Sitka spruce if present goes into check.

Choice of species is very restricted on the heaths. With the exposure one is largely limited to *Pinus contorta* although Mountain pine (*P. mugo*) can also be used. Farther inland provided there is a reasonable depth of raw humus plus leached layer, which is not over frequently found on the top of morainic knolls, Scots pine can be planted. On the poor flushes between the morainic knolls one is largely confined to *P. contorta*.

3. *Planting*

Borgie was an early Commission forest in the North Conservancy, planting being started in 1920 but all the early plantings were destroyed by fires in 1929 and again in 1942 and replanting with ploughing started in 1943. Planting started at Rumster in 1949, at Strathy in 1954, Dunnet in 1955, and Naver in 1958. The research plots were laid down in 1949 onwards. Planting has, of course, been entirely on ploughed ground and has followed along normal lines. Manuring with phosphates is necessary on most of these areas. In practice 2 ounces per plant of ground mineral phosphate has been given to Sitka spruce and on the poor ground 1 ounce per plant to the *P. contorta*.

4. *Success of species planted*

Scots pine will undoubtedly have general use at Naver which is well inland. Elsewhere only isolated pockets have been planted. On Rumster where exposure is severe it has failed. In a remnant of the original Borgie plantings Scots pine has grown very well on a sheltered bracken area, but this area was largely destroyed in the 1953 gale. On the poor *Scirpus* peats of Strathy in the research areas Scots pine of west coast origin planted on mineralized peat has grown quite vigorously. Although little attention has been paid to origin there is no doubt that it is of supreme importance on these exposed sites.

Corsican pine has been used on an extensive scale at Dunnet on pure sand with a pH value of 8·8. It is too early to form any impression on this species as yet. Heavy deaths were sustained following the drought of 1955.

On the poor exposed *Scirpus* peats and heaths of the north and west it is becoming increasingly obvious that forestry hopes must lie with *Pinus contorta*. The post-fire plantings of *P. contorta* at Borgie have been singularly unsuccessful. There may be various reasons for this lack of success. Only in recent years has a plentiful supply of *P. contorta* seed become available and most of the plants used in the 1943–53 plantings were either 1-year or more generally 2-year seedlings. A number of years ago the sole source of seed was the older Commission plantations and it is believed that the origin of these was mostly of an inland type. Allied to this was the fact that *P. contorta* was indubitably planted in the poorest of poor soils, Sitka spruce being used widely on the poor flushes which were certainly of better quality than the drift-covered morainic knolls. More recently, particularly in the research P 49 areas at Strathy and Watten *P. contorta* of the Pacific Coast, Washington County origin has grown rapidly, in some cases too rapidly, on poor *Scirpus* peats, although the rate of growth can probably be attributed to too much manure. It can be accepted that initial establishment of *Pinus contorta* on blanket peat (Fig. 8) is possible but there are still two obstacles to the trees reaching a utilizable state. The first obstacle is the absence of sufficient nutrients in the soil although this may be overcome by the scientific application of manures. The second obstacle, which is the greater of the two, is the danger of windblow. By the time the trees reach a height of 30 feet they will still have a very shallow root system which may well provide insufficient anchorage for trees of that size. The heights of the *P. contorta* at present are probably 10–12 feet so that there must still be considerable doubts about growing a pole crop on blanket peat.

In relation to the growth of this species the origin of the *P. contorta* seed is of paramount importance. There are unfortunately not a great many origins planted in the far north but unquestionably the most successful is Pacific Coast, Washington County. The trees of this origin are of a very rough branched vigorous growing type and have the appearance of being top heavy and very unwindfirm. Certainly in the *P. contorta* races experiment in the Black Isle planted in 1938 there has been considerable windblow and there are a great many swept butts in the Pacific Coast origin plot. The plot has now a very ragged appearance. In view of this it is probable that trees of a more compact form would be more suitable. Undoubtedly Queen Charlotte Island origin is a much more desirable coastal type of tree if one can go by results in the race plots. Alternatively Prince George which comes from a more inland area is of an equally good form.

Very little Japanese larch has been planted but such as has been has done rather poorly and it is not likely to prove of much value on poor exposed soils. Similarly Douglas fir and Norway spruce offer poor prospects except in sheltered corners of good deep soil.

Sitka spruce has again been planted on far too wide a scale even up to fairly recent times. At Borgie and to a much lesser extent at Rumster there were considerable areas planted with this species particularly on the poor flat or gentle sloping flushes with a vegetational cover of mainly *Scirpus* plus heather and *Molinia*. On the deeper peats following on ploughing the vegetation became predominantly *Molinia* but reverted to heather after about 5 years. On the shallower peats heather growth became more luxurious but was still intermingled with *Scirpus*. On these areas Sitka spruce has at Borgie failed rather miserably. At Rumster where the *Molinia* has persisted for a longer period obviously on better flush conditions Sitka spruce has done moderately well but with the coming of the heather it is going into check. In all cases phosphates were applied at the time of planting and on trial areas the dose has been repeated on two further occasions. Good results were obtained from the first dose but the last dose applied had little or no effect probably due to the fact that supplies of other nutrients, nitrogen, potassium, and magnesium are exhausted. Today there is little doubt that *Pinus contorta* would be planted instead of Sitka spruce. On such

soils one is apt to consider *P. contorta* as a pioneer crop and assume that if it can reach a utilizable size the more exacting Sitka spruce can follow as the second crop. As yet there is little evidence that *P. contorta* will improve the peat sufficiently for this aim to be attained.

At Borgie and Rumster there are very few good flushes but where these are found the prospects for Sitka spruce are good. Small patches of Sitka spruce mainly by the Borgie River on alluvial ground and again at Borgie Beag on *Molinia* ground which escaped the fire, have grown reasonably well.

5. Beating up

There has been no abnormal number of deaths except at Dunnet following the drought of 1955 and a sandstorm in April of 1956 when a large number of *Pinus contorta* which were growing rather well were killed. The exposure at Dunnet is such that shelter will require to be built up either gradually, initially taking advantage of the dunes which are being fixed or alternatively by artificial means, and experiments have been laid down to this end. More Corsican pine will have to be used at Dunnet than heretofore.

Elsewhere Sitka spruce deaths have been replaced with *P. contorta*.

6. Thinning

Two small plots which survived the fire at Borgie have been thinned on occasion but considerable damage to these blocks was done in the 1953 gale and thinning has taken the form of opening up the remaining clumps.

7. Utilization

The thinnings have been mostly sold locally for repair work on crofts. The blown timber which amounted to some 16,000 hoppus feet was sold as pitwood and boxwood logs.

WEST COAST FORESTS

A. Description

1. Forests in the group

There are nine forests in this group—Lael, Slattadale, Achnashellach, North Strome, South Strome, Inverinate, Ratagan, Glenshiel, Eilanreach. All lie on the west side of the main watershed except for the two eastern blocks of Glenshiel.

At Achnashellach there is one of the main research areas in the north where the problems of afforestation, on poor *Scirpus* peat overlying morainic deposits, is being investigated.

Table VII gives details of areas.

2. Land utilization

The areas now occupied by the coastal forests were formerly sheep farms whereas the higher lying inland areas were generally deer forests (Glenshiel and Achnashellach). Remains of the natural forest both hardwood and coniferous can be seen in the district and on Loch Maree side can be found small areas of natural regeneration of Old Caledonian pine.

3. Physiography

Most of the plantations in these west coast forests have been established on steep to very steep slopes. Many of the forests are situated on the north and south shores of the sea lochs whose axes lie in a north-west to south-east direction. Loch Carron is the exception. Elevation varies from sea-level in the coastal forests to 1,000 feet at Ratagan. At Glenshiel the elevation varies from 600 feet on the valley floor to 1,300 feet at the top limit of planting. All aspects are found but the majority are north-east or south-west.

4. Geology and soils

Most of the forests lie on or near the plane of the Moine Thrust and in consequence the geology is complex.

At Lael, Achnashellach, Inverinate, and Eilanreach the basic rock is Moine schist with areas of Torridonian sandstone at Achnashellach and Lael and Lewisian gneiss at Inverinate. There are smaller areas of Cambrian sediment at Lael and Achnashellach. Where mica schist and hornblende schist outcrop in the Moine schist good growth results.

TABLE VII. *West coast forests. Land utilization as at September 1957*

Forest	*County*	*Area of acquired plantations (acres)*	*Area planted by Forestry Commission (acres)*	*Area awaiting planting (acres)*	*Unplantable agricultural or other (acres)*	*Total (acres)*
Achnashellach	Ross and Cromarty	10	920	24	18,720	19,674
Eilanreach	Inverness	..	829	..	93	922
Glenshiel	Ross and Cromarty	..	763	..	2,890	3,653
Inverinate	Ross and Cromarty	1	1,037	..	196	1,234
Lael	Ross and Cromarty	11	2,155	492	925	3,583
North Strome	Ross and Cromarty	..	863	49	1,057	1,969
Ratagan	Ross and Cromarty and Inverness	29	1,561	530	3,352	5,472
Slattadale	Ross and Cromarty	71	796	..	528	1,395
South Strome	Ross and Cromarty	12	1,234	2	2,308	3,556

At North and South Strome the basic rock is Lewisian gneiss with Torridonian sandstone at North Strome while Cambrian sediments are found in both forests. There are a few instances of particularly good soils on land mapped as Lewisian gneiss, e.g. Fernaig, South Strome.

Slattadale lies mainly on Torridonian sandstone with small areas of Lewisian gneiss which appears to break down more readily in some parts than in others.

Ratagan is a mixture of Moine schist and Lewisian gneiss with a considerable area of granite. There are patches of hornblende, serpentine, diorite, and pelitic schist and it would appear by an inspection of the boulders that there has been a certain movement of these over the granite, Moine schist, and Lewisian gneiss.

There are small areas of epidiorite or hornblende at North and South Strome and adjacent to Slattadale and wherever these and other such intrusions are found soils are of good quality. Birch/alder slopes are often associated with these intrusions.

Morainic drift covers the solid bedrock on the lower ground and is often more extensive than appears at first sight. At lower levels on the steep slopes creep soils overlie the drift. Farther up the slopes these soils give way to peat, which is fairly shallow over the numerous morainic knolls. The peat is deeper between the knolls. Leaching is common and pan formation is not unknown. It should be noted that morainic knolls vary greatly in composition and quality. One extremely important factor from the forester's point of view is the depth of peat on the knoll.

5. Vegetation

Hardwood scrub occurs on the heavy and minerally rich soils on the lower valley slopes. Where there is no hardwood tree layer, the ground vegetation is mainly composed of the

finer grasses with *Anthoxanthum* and the finer mountain grasses on the lower ground giving way to *Festuca*, *Molinia*, and *Nardus* on the middle and upper slopes. There is, however, a marked absence of *Deschampsia flexuosa*. Bracken frequently occurs on creep soils. *Calluna* and *Scirpus* are the main species on the moraines with *Calluna* dominant on the lower ground and *Scirpus* with sparse *Calluna* at higher altitudes. The heather on the west coast moraines is less vigorous in growth and more open in stocking than that of the east coast heaths.

Associated with the *Calluna* and *Scirpus* are varying amounts of *Molinia caerulea* and cross-leaved heath (*Erica tetralix*) in the wetter areas. On flushed peats, *Molinia* becomes dominant. On flushed mineralized peat, the rushes *Juncus articulatus* and *J. communis* and bog myrtle *Myrica gale* are generally found. On the drier knolls, *Erica cinerea* is a component along with *Scirpus* and *Calluna*.

6. *Climate*

The climate is essentially mild and wet. The annual rainfall varies from 60 inches near the coast to over 100 inches at Achnashellach and Glenshiel and is fairly evenly distributed throughout the year although spring droughts frequently occur despite the high rainfall. Frosts are infrequent and are absent in some places. May is the driest month. The prevailing winds come from the south-west. The high hills which separate the sea lochs afford shelter at low elevations. Higher ground is often exposed. High winds with heavy rainfall are frequent and heavy windblows have occurred recently notably at North Strome where 30 acres of P 26 Douglas fir were blown in February 1957.

B. Silviculture and Management

A number of the older forests in the Conservancy are to be found in the west coast group, in fact the land on which most of the forests in the group are established was acquired in the first decade of the Commission's life. Achnashellach, Slattadale, and Ratagan were acquired in 1921, Glenshiel in 1924. North Strome and South Strome in 1925 and the remainder between 1925 and 1929. Owing to the improvement in sheep prices from the middle thirties no further land was obtainable until the last year or two. In three of these (Achnashellach, Slattadale, and Glenshiel) the quality of the land which was then planted was poor; ground was planted which, even with our present experience and knowledge, is still considered unplantable. Most of the planting was carried out with Norway and Sitka spruce and Douglas fir and overaged plants were commonly used which may yet bear harmful results.

1. *Ground preparation*

On areas carrying oak scrub, the trees were felled and split oak posts prepared for use locally. On odd occasions the oak was girdled as was the case generally with birch scrub. It was usual for a scattering of hardwood to be left on the area, its value as a nurse being recognized from the start.

Despite the fact that all the forests in this group are located in the area of high rainfall, little drainage was done in the early Forestry Commission plantations. On creep soils the natural drainage was generally good and no difficulty was experienced in getting the trees to grow. In birch scrub far too few drains were cut. With the collapse of the roots of the birch which were ringed the whole surface became sodden, as for example at South Strome. All species were notch planted. The initial take was good and the trees have continued to grow satisfactorily. Failures arose when similar practices were tried on the peat soils. Peat soils in areas of high rainfall were extensively planted with spruce, mainly Norway

spruce. Current practice at the time was to notch the spruces into the peat. Many subsequently either died or went into 'check'. By the middle twenties the bulk of the spruce plantations on peat were most unsatisfactory. In 1923 H. M. Steven produced a report 'Root Form on Peat' which showed that the nursery root system of spruce trees planted into poorly drained moorland invariably became moribund; only when the plant had developed a completely new system from adventitious roots did the trees commence to grow at all well. Steven records that the new roots operated almost entirely on the surface of the peat and ran 'mainly through the herbage plant remains' (Zehetmayr, 1954).

Inadequate drainage was thought to be the main reason for the unsatisfactory growth but extra drains provided in the mid twenties did little to improve the growth except on the more fertile sites. In 1925 the Research Branch started the use of shallow inverted turf which on account of encouraging results became standard Commission practice by the middle 1930's. It is believed, however, that adequate drainage dates from 1931. Manuring with phosphate was started in 1932 which with the improved draining gave startling results. Large areas of climatic peat were successfully planted using these treatments. On shallow peat overlying moraine this treatment using spruce met with little success.

Some areas planted since 1945 have been ploughed. Where the slope was suitable, the morainic ridges and knolls were ploughed with the Ross tine, and the flushes by the single furrow Cuthbertson. On steep ground which cannot be ploughed, turfing and manuring as practised in the 1930's is still the standard procedure.

2. Choice of species

In the 1920's the main species planted on good creep soils were the spruces, Sitka and Norway, Douglas fir and the larches, European, Japanese, and on a smaller scale, hybrid. In those forests with a relatively high proportion of creep soils and where the bedrock is fairly rich, growth has been consistently good (South Strome, Inverinate, Ratagan, and the Glenbeag section of Eilanreach). Today there are substantial areas of pure blocks of these species in these forests. Perhaps the least successful species of those mentioned above has been European larch. In the early days this species was confined to moist grass/bracken ground, sites which today would be planted with one or other of the spruces. Wind sway in the early years resulting in sabre butts was common in larch and Douglas fir and undoubtedly this was partly due to the use of oversized plants.

When the Commission started planting, the silvicultural characteristics of Sitka spruce were not fully understood. It was thought then to be less resistant to exposure and more demanding of fertile soils than Norway. Consequently in the first decade of planting, Sitka was confined to the more fertile sheltered ground while Norway was planted on the poor exposed soils (Ratagan, parts of South Strome, and Slattadale). The result of that selection today is that there are some very vigorous stands of Sitka spruce and some rather poor stands of Norway spruce some of which have been replanted with a different species or are still in check.

The most disappointing plantations are those formed on the thin peat overlying morainic deposits (west end of Slattadale, Glenshiel, Achnashellach, and parts of the Loch Duich section of Ratagan). The species planted on these soils were mainly the spruces, Norway and Sitka. Of the two, Norway was more widely used than Sitka. In the Working Plan for Glenshiel made in 1927 for the period 1928–32, the choice of species is prescribed as follows, 'A climate of high rainfall combined with a generally peaty condition of the soil indicates that the area must be predominately a spruce one.' Growth was unsatisfactory from the start. The first attempts at rehabilitation were to cut more drains and to beat up with the same species as was used in the original plantings but the additional draining failed

generally to induce growth. From 1928 the beat up plants were turf planted. In the early 1930's it became evident that the spruces were unlikely to grow satisfactorily on such soils, and recourse was made to other species for beating up. Japanese larch, *Pinus contorta*, and Mountain pine were interplanted amongst the checked spruce and manured. At this time, there was still a reluctance to plant Scots pine. More intensive draining, turf planting, and manuring created the optimum conditions for the beat up plants and they grew from the start, at the same time nursing the checked spruce but generally their more rapid growth has resulted in the spruces being suppressed. In some places the nurse species has been sacrificed for the spruce. An intimate mixture of species at the present time indicates areas where initial establishment was difficult and prolonged. Some areas originally planted, but now considered unplantable, have been abandoned (Achnashellach, Slattadale, and Glenshiel). Current practice is to plough the morainic ground with a tine plough where the slope of the ground permits. On the better sheltered ground where the peat cover is less than 6 inches, pure Scots pine can be planted; on the poorer areas a mixture of Scots and *Contorta* pine is possible. Where exposure is severe, the choice is narrowed to *Pinus contorta* and Mountain pine. The demands of both species are somewhat similar but *Contorta* grows much faster. Where the depth of peat is over 6 inches the safest species is *Pinus contorta*.

On flushed peats, the choice of species depends on the richness of the flush. The most favourable species ranging from the poorest to the highest grade of flush are *P. contorta*, Sitka spruce, and Norway spruce respectively.

3. *Planting*

The first Commission plantings on the west coast were at Achnashellach and Slattadale in 1922. By 1930 the bulk of the planting in the group of forests had been completed. The annual rate per forest varied from 100 to 150 acres but the rate was drastically reduced about 1928 at those forests where large areas of earlier plantings were showing up as unsatisfactory. Up to 1928 the normal method of planting was by vertical notching using the mattock and later the Schlich spade. Plants were notched into all types of soil. By 1928 some turf planting was being done and by the middle 1930's this method became general on the peat areas. Since 1945 new areas have generally been ploughed where ploughing was possible.

4. *Success of species planted*

Sitka spruce. Sitka spruce is the biggest volume producer in the west on the heavy mineralized soils and in flushes. Growth is slow where the species has been planted on shallow peat over moraines. It is one of our most wind resistant trees and because of that it has been planted since 1930 on the higher plantable ground, on the deeper peats dominated by *Molinia caerulea*. On the more fertile soils the quality class varies from II to III. At Slattadale there is one stand verging on quality class I.

Norway spruce. Although its rate of growth to date is much less than that of Sitka on fertile soils this species has grown most satisfactorily. There are quality class I stands at Slattadale, Achnashellach, North Strome, and Ratagan. Mention has already been made of its poor growth on thin peat overlying moraines. Many of the trees have been suppressed by the interplanted pines and larches where these were used to replace the failed spruce.

Japanese larch. This species has grown vigorously everywhere in the west except in the Lechanashie section of North Strome. Form varies considerably. There is an excellent stand of good form in the P 23 area at Ratagan. By way of contrast, there are some appallingly crooked trees in Inverlael glen, Lael Forest. Crookedness seems to be correlated

with fertility of site. Best form is obtained on low-lying sites dominated by a grass/heath vegetation (North Strome). It can grow reasonably well on relatively poor soils, but it cannot withstand too much exposure.

European larch. Some excellent stands of European larch were grown in the past on the west coast. It is probable that insufficient attention has been paid by Commission officers in the past to site and seed origin which may well account for the considerable areas of poor European larch. Mention has already been made about the planting of this species on relatively flat grass/bracken sites—ground which today would automatically be planted with one of the spruces. The species has been prone to canker and die back and losses have occurred but the climax of the attack seems to be past and the trees which remain appear healthy. At Lael, this species was replanted on a felled woodland area. Growth has been very good—there are a number of quality class I stands but *Fomes annosus* is prevalent.

Hybrid larch. The growth of this species has been most satisfactory. There are excellent stands at Ratagan, South Strome, and Achnashellach all planted in 1926. Some later plantings at Lael are of equally good form although growth appears to be less vigorous.

Scots pine. The area of this species in the west coast group is relatively small. In the first decade it was seldom planted. In the 1930's it was used to a limited extent in mixture with Sitka spruce on shallow ground with a fair proportion of heather (*Calluna vulgaris*) in the surface vegetation. It was strongly advocated by the late Lord Robinson for use in pine/spruce mixtures because it suppressed the ground vegetation much more effectively than did *Pinus contorta*. It has grown well locally in sheltered areas but it cannot withstand exposure. In the past, too many plants of east coast origin were planted in the west. It is now Conservancy practice to plant Scots pine raised from seed collected off trees grown in the west coast forests. The main sources of seed supply are the indigenous stands at Slattadale and Achnashellach. There is still a place for Scots pine of west coast origin on the more sheltered grass/heath ground and on some of the better quality moraines. The latter sites need to be subsoiled with a tine plough.

Corsican pine. Only very small areas have been planted with this species. To date its growth is encouraging. Its soil requirements are similar to Scots but it will stand more exposure. Salt laden winds seem to have little effect on it and because of that it could be planted more extensively in the coastal forests, although even where it does well it has a crown which is thin.

Pinus contorta. This species was used sparingly in the 1920's, but in the early 1930's it came to play a bigger part in the reconstruction and rehabilitation of the large areas of checked spruce. It is fairly resistant to exposure and will grow reasonably well on the poorest of soils. Its use is confined mainly to the deeper unflushed intermoraine and basin peats where *Calluna/Scirpus* is the dominant vegetation. Both coastal and inland varieties have been used. *Contorta* was used to beat up checked spruce areas.

Douglas fir. Like Sitka spruce this species is a high volume producer on creep soils. On former broadleaved scrub areas it has grown rapidly (North Strome) but it appears to be unstable in middle age. Optimum sites are deep sheltered valleys. Windblow is a problem in stands over 30 years in exposed localities. Two areas of poor type are to be found in South Strome and Ratagan: in both the seed origin seems to be dubious.

5. *Beating up*

This has been largely dealt with under 'Choice of Species'. This operation was mainly confined to those forests where there were extensive areas of poor soils. The amount of beating up at a forest such as Glenshiel has been very high.

6. *Weeding*

Weeding has never been a major operation at any of the west coast forests, except in localized areas of strong dense bracken and strong *Molinia*. In the early 1920's heather burning and bracken cutting one or two years ahead of planting was the normal practice at the time. From 1920 to 1925 records indicate that weeding tended to be overdone. In the early 1930's lack of money prevented a lot of essential weeding being done. Although there were undoubted losses then the overall position was never serious.

7. *Thinning*

Mention has already been made of the good growth of all species planted on creep soils, yet up to the end of the Second World War little thinning was done. Of the little that was done the grade in all cases was light. Lack of roads and markets made the disposal of produce difficult. After the war a heavy road-making programme was undertaken. The road system, started in 1946 on a small scale, began to bear fruit in 1949–50. Areas where thinnings were delayed because of lack of access were brought within the range of economic extraction. No great difficulty was experienced in some areas in recruiting the necessary staff to deal with the thinning but at Slattadale slow progress was made because of the lack of labour. By 1957 most of the west coast forests had a basic road system and in all of them the thinning position is now satisfactory with the possible exception of Ratagan. On fertile soils the larches and Douglas fir were generally the first to reach the thinning stage. Japanese larch planted in 1923 at Ratagan was ready for thinning in 1938. One compartment of European larch at Lael was thinned when 13 years old. Sitka spruce and Douglas fir are ready at about 20 years, and the pines at about 25 years. Average volumes per acre removed have been for the larches and Norway spruce 350–500 hoppus feet, Sitka spruce and Douglas fir 500–700 hoppus feet, but heavier volumes of up to 1,000 hoppus feet (mainly at the second thinning) have been removed where the thinnings have been delayed. Current practice is to thin to a C/D grade for the fast-growing species. Thinning cycles are normally 3 to 4 years.

8. *Utilization*

Because of the remoteness from the main timber trade centres on the east coast and shortage of labour, the timber merchants have been unwilling to buy thinnings standing. Only at one forest has it been possible to sell standing thinnings (Ratagan). The main method of disposal at the present time is in the length at roadside, the timber being transported to main conversion depots in the Great Glen and on the east coast. A single bench mill was erected at Ratagan 5 years ago and the old estate mill was acquired at Lael. These mills are used mainly for the sawing of fencing posts and boarding to supply the timber required for the Commission and local fencing needs in the west and on the islands.

WEST COAST FORESTS OMITTED FROM WEST COAST FOREST GROUP

Three forests have been omitted from this group, viz. Glencripesdale, Glenhurich, and Sunart. Glencripesdale and Sunart are recent acquisitions. Most of the land acquired at Sunart is covered with natural scrub oak growing in pockets of soil between rocks. The soil at Glencripesdale is variable, often shallow with a fairly extensive area of good deep soil at the back of the old mansion house. This recently carried a good coniferous crop, the larch being particularly good.

Glenhurich is a forest acquired in 1923. It is extremely isolated and difficult of access. With the exception of the steep upper slopes and the morainic knolls the area is peat covered to a normal depth of 12–18 inches. The steep slopes are of good quality mineral soils

covered by grass and bracken. About three-quarters of the planted area is covered by Sitka spruce of variable growth. The thinning yield per annum is about 60,000 cubic feet but shortage of labour reduces the production to about half that figure.

Area figures for these forests are given in Table VIII.

THE GREAT GLEN FORESTS

A. General Description

1. *Forests in the group*

The forests described in this group are located on the valley slopes of the Great Glen itself and also in the valleys of the rivers flowing into the Great Glen lochs. There are thirteen forests in all: Glenurquhart, Creagnaneun, Farigaig, Ceannacroc, Port Clair, Inchnacardoch, Glengarry, South Laggan, Clunes, Glenloy, Leanachan, Nevis, and Glenrigh.

Table VIII. *West coast forests omitted from West Coast Forest Group. Land utilization as at September 1957*

Forest	*County*	*Area of acquired plantations (acres)*	*Area planted by Forestry Commission (acres)*	*Area awaiting planting (acres)*	*Unplantable agricultural and other (acres)*	*Total (acres)*
Glencripesdale	Argyll	..	323	1,845	4,482	6,650
Glenhurich	Argyll	..	3,058	743	11,379	15,180
Sunart	Argyll and Inverness	49	1,060	920	540	2,569

Within Inchnacardoch Forest there is the important experimental reserve on the Lon Mor and at Glenrigh Forest there is a smaller experimental area at Inchree. The Lon Mor is one of the important sites used for the experimental planting of poor peat. It was selected as a typical stretch of deep peat in contrast to the shallow peat used at other forests. The Inchree area is more akin to that at Achnashellach. Here the morainic knoll forms a conspicuous feature of the topography and the peat is generally thin. Particulars of area are given in Table IX.

2. *Former utilization*

There is evidence that a lot of the ground was covered by trees in the distant past. Moor log has been exposed under 4 feet of peat in the Lon Mor. Mention has already been made of the existence of a bloomery for the smelting of iron at Glengarry, the local timber being used as fuel to fire the furnaces. No doubt certain areas were cleared of trees in the early eighteenth century by the English soldiery for tactical reasons, although there are records that Baltic timber was used in the construction of the fort at Fort Augustus. Other areas were later cleared for sheep grazing and arable agriculture. At the time they were acquired, all the forest areas west of Glengarry were sheep farms, those east of Glengarry were mainly deer forests.

3. *Physiography*

Apart from Ceannacroc which is relatively flat all the other forests in this group have been established on steep to very steep slopes (Fig. 12). Forests in the Great Glen itself

have either a north-west or south-east aspect depending on which side of the main valley they are situated. Forests in the valleys leading into the Great Glen have north and south aspects generally. Plantations are found at all elevations from sea-level at Glenrigh to 1,000 feet at South Laggan and 1,100 feet on the south side of Glenurquhart. Exposure is nowhere particularly severe.

4. *Geology and soils*

There is no detailed geological survey for many of the forests in this area but the bedrock is mainly schistose. Creagnaneun is mainly on Old Red sandstone as is Farigaig on the

TABLE IX. *Great Glen Forests. Land utilization as at September 1957*

Forest	*County*	*Area of acquired plantations (acres)*	*Area planted by Forestry Commission (acres)*	*Area awaiting planting (acres)*	*Unplantable agricultural or other (acres)*	*Total (acres)*
Ceannacroc	Inverness	68	1,600	2,447	15,766	19,881
Clunes	Inverness	15	1,846	819	4,581	7,261
Creagnaneun	Inverness	..	1,364	6	552	1,922
Farigaig	Inverness	578	1,392	1,482	3,567	7,019
Glengarry	Inverness	116	4,765	957	17,190	23,028
Glenloy	Inverness	10	1,936	101	499	2,546
Glenrigh	Inverness	..	2,508	22	3,353	5,883
Glenurquhart	Inverness	38	3,604	1,484	11,150	16,276
Inchnacardoch	Inverness	63	2,381	374	6,533	9,351
Leanachan	Inverness	6	2,929	3,472	12,730	19,137
Nevis	Inverness	..	977	3	6,679	7,659
Port Clair	Inverness	..	2,347	6	3,147	5,500
South Laggan	Inverness	19	1,091	..	3,085	4,195

opposite shore of Loch Ness. Parts of South Laggan on the south side of Loch Oich are also on Old Red sandstone. There is limestone on the south west side of Leanachan which is quarried. The solid geology in the Sallachail block of Glenrigh is mainly slate. Only at Inchnacardoch and Port Clair has a special survey been made of the geology and soil. Over the greater part of these forests the bedrock is of rather poor moine schist: at the western end of Inchnacardoch the rocks are of foliated granite or granite gneiss. In general on the higher slopes grey drift overlies the moine schists while on the lower slopes the readvanced moraine has left deeper depositions of soil.

The soils in the eastern half of the Great Glen are generally relatively rich. The area of felled woodland replanted has been comparatively small but extensive areas of plantations have been established on areas which previously carried hardwood crops of birch and oak. Beyond the hardwood tree limit, the soils on the eastern half of the Glen are light and sandy in texture, but from Glengarry westwards peat predominates—mostly *Molinia* peat.

5. *Vegetation*

Substantial areas carried a tree layer of scrub birch and oak, the ground vegetation being grasses, bracken, and mosses. There are considerable areas of scattered natural Scots pine at Glengarry, Ceannacroc, and Glenloy; the ground vegetation on these pine areas is that normally associated with a pinetum. Beyond the tree and scrub zone the vegetation on the plantable ground in the eastern half of the Glen is mainly heather on the moraine ground

with a mixture of heather and *Molinia* in varying proportions on the inter-moraine peats. These conditions generally prevail in the forests east of Glengarry. From South Laggan westwards there is a decreasing amount of heather and a corresponding increase in the quantity of *Molinia* and fine grasses. Morainic ridges and knolls in the western forests, like their eastern counterparts, are dominated mainly by heather and *Scirpus* but the heather in the west is less vigorous and more open in stocking.

6. *Climate*

The average annual rainfall is 35–40 inches at Glenurquhart increasing to about 100 inches at Glenrigh. The driest month is normally May. Forests in the subsidiary valleys are fairly sheltered except at the higher elevations; those in the main glen are relatively more exposed, exposure becoming greater as one approaches the west coast. The prevailing wind is south-west but occasionally strong winds from the north-west cause a certain amount of windblow, especially if they are accompanied by heavy rain. Frost and snow are generally not troublesome but occasionally late and early frosts damage nursery stock at Inchnacardoch.

B. Silviculture and Management

In 1911 the Great Glen was the subject of a survey and report by Lord Lovat and his brother-in-law Captain (later General) Stirling of Keir, which was published by the Royal Scottish Arboricultural Society. The Survey was made to demonstrate the great possibilities for forestry in the Highlands and to give force to the view strongly held by Lord Lovat and others at the time that a forest authority should be set up to extend, on a large scale, the forest area of the country. The areas planted later by the Forestry Commission follow very closely the boundaries of plantable land as assessed and mapped in that report. The species, however, do not follow so closely the recommendations made in the report which advocated the use of European larch and Norway spruce to an extent quite incompatible with the nature of the ground.

All the forests in this group were acquired in the first twelve years of the Commission's existence except Farigaig and Ceannacroc although there have been recent additions to some of the forests.

1. *Ground preparation*

(*a*) *Areas carrying hardwood trees and scrub*. There were few if any markets for the hardwood scrub even although some of the oak was better than scrub. Various forms of treatment from clear felling to selective clearing of the scrub were carried out. One such clearing was tried in a section of Creagnaneun carrying a crop of natural oak by Dr. (now Professor) Anderson. Groups were cut in the oak at 24 feet centre to centre, and into each group eighteen plants were notched. The main species planted was Douglas fir but smaller amounts of *Tsuga* and Norway spruce were also tried. Plant spacing was 3 feet. Generally where the scrub growth was predominantly birch, the birch was clear felled and only the minimum of draining done.

(*b*) *Bare ground*. Where the vegetation was mainly heather, the heather was burned in advance of planting and some draining done. Likewise where natural drainage was good on the steep creep soils little drainage was carried out. More draining was done in the peat soils in the west but the intensity of draining was generally inadequate until turf planting became normal practice about 1930. Current practice is to plough deep peat at 5-foot intervals where the topography permits with a Cuthbertson single furrow plough and the morainic ridges and knolls with a tine plough. On ground too steep to be ploughed, hand draining and turfing is resorted to.

2. *Choice of species*

One of the main considerations in the early days of the Commission was to select species for planting which would yield a heavy volume. On the old hardwood sites and felled woodland areas, Douglas fir was planted extensively in the 1920's. In the forests in the higher rainfall belt farther west, the choice was largely spruce, both Norway and Sitka. Table X shows the preponderance of Douglas fir at Glenurquhart, Creagnaneun, Port Clair, and Inchnacardoch. From South Laggan westwards spruces are the main species planted. The high percentage of Scots pine at Inchnacardoch is accounted for largely by the Blar an Righ heath being planted with this species and also the extensive use of Scots pine in the replanting of the checked Norway spruce areas. Difficulties arose in the early days

TABLE X. *Great Glen Forests. Percentage stocking by species in 1947*

Forest	*Douglas fir*	*Sitka spruce*	*Norway spruce*	*Scots pine*	*Others*
Glenurquhart	32	5	28	16	19
Creagnaneun	33	2	41	20	4
Farigaig	..	..	..	..	..
Ceannacroc	..	..	..	..	..
Port Clair	47	6	45	1	1
Inchnacardoch	21	3	17	53	6
Glengarry	2	36	58	2	2
South Laggan	1	48	41	1	9
Clunes	..	30	60	6	4
Glenloy	..	60	29	1	10
Leanachan	..	86	6	1	7
Nevis	3	71	..	1	25
Glenrigh	5	53	39	1	2

with the planting of the heather clad morainic ridges and knolls with spruce. By 1925 fairly extensive areas were showing up as unsatisfactory.

There was general reluctance to use Scots pine because of its relatively low rate of volume production. By 1930 its use was being advocated for the replanting of the failed spruce areas. The pines grew well on the better moraine ground and have now reached the thinning stage. Some of the checked spruce have been nursed by the pines and in many of the pine plantations, especially at Inchnacardoch, there is a sparse under-storey of Norway spruce which is being ignored in the management of the pine plantations. The failure of the spruces on the morainic knolls in the plantations on the north side of Loch Lochy accounts for the rather 'moth eaten' appearance of the plantations there. Attempts have been made to replace the spruce with pine but it has been difficult to get the pine established in the presence of a heavy deer population.

Small areas of the two main *Abies* species have been planted in most of the forests. Generally they were planted on good sites.

3. *Planting*

Inchnacardoch and Port Clair were acquired in 1919 and the first plantings were done the following year. Planting was started on the other forests soon after acquisition and was

completed before the war except in the case of the post-war acquisitions at Farigaig and Ceannacroc. The early planting method was mainly notching with Mansfield, Schlich, or garden spade. Big plants over limited areas were pit planted. In the middle 1920's the mattock was frequently used in an attempt to get shallow planting without the use of turfs. Dr. Anderson's experiments on the Lon Mor in 1925 on turf planting and manuring, however, revolutionized planting techniques in this Conservancy and farther afield. Turf planting of spruce was started in 1928 and became general practice by about 1930. The application of a phosphatic manure, in addition to the turf planting, resulted in a quite exceptional stimulus to growth. By 1932 the application of 2 ounces of ground mineral phosphate to spruce planted on the poorer peats became normal Conservancy practice.

4. *Success of species planted*

Douglas fir. This species was widely planted on relatively fertile sites normally covered by hardwood scrub and bracken in the forests at the eastern end of the Great Glen. Growth was good from the start and today there are many excellent stands of Douglas fir at Port Clair and Creagnaneun. There is a particularly fine stand in the Torr Dhuin section of Inchnacardoch. The trees are straight-growing and finely branched.

Sitka spruce was planted on sites similar to those for Douglas fir in the forests at the western end of the Glen. The belief was held that this species was more sensitive to soil conditions, wind, and frost injury than Norway spruce and in consequence it was confined to the lower and richer slopes on which it has grown exceptionally well. Norway spruce was relegated to the more exposed and less fertile peat soils. By 1930 it was realized that the silvicultural characteristics of the species should be reversed, Sitka being the tree for the soils formerly planted with Norway. Sitka spruce was planted extensively on the *Molinia* peats in the western forests and on these soils it has grown well. On heather-clad morainic knolls it has, as elsewhere, checked. On the inter-morainic peats its growth has been variable. With additional draining and on occasion a second application of ground mineral phosphate it has been possible in many cases to get the species out of check. On the poorer ground areas of checked growth are gradually decreasing but there appears little hope at present that on shallow peat over morainic knolls, a closed canopy will ever be attained.

It has already been recorded that Norway spruce was planted on a wide scale on ground now known to be unsuited to the species. On old hardwood scrub sites it has grown well. Some of the higher land on which it was planted has been left meantime until experiments indicate what methods and species will guarantee success. Current practice is to confine the species to hardwood scrub areas, grass/bracken, and rich *Juncus* sites.

Scots pine was used very sparingly in the early years but it was given greater consideration in the 1930's as a substitute species for the checked spruce on heather-clad ground and has grown well. Small quantities of European larch were planted. In many cases it was confined to ground more suited to spruce. Japanese larch was used on a limited scale in the west end of the Great Glen normally on good quality ground where growth has been good but form bad. Growth of the *Abies* species has been good. An *A. grandis* stand in Port Clair is the fastest growing plot of its kind in the country (Fig. 9).

5. *Beating up*

In some forests this operation was both expensive and extensive. Large areas of checked spruce were virtually replanted. The practice in the early years was to replace failures with the same species on the assumption that the original choice of species was correct. By the late 1920's it was realized some species were unsuitable and efforts were made to introduce in the beating up a species more suited to the site. The following extract about beating up

from the Plan of Operations for Inchnacardoch for the period 1931–5 is illuminating, '(*a*) Plant dry slopes and knolls where spruce have failed with Scots pine (some Japanese larch on the lowest slopes) (*b*) Plant the better types of flats and hollows with Sitka spruce by intensive draining, turfing and application of slag. In places, the process will amount to a replant.'

6. *Weeding*

Local areas of bracken were troublesome but appear to have been adequately and timeously dealt with. On many areas too much overhead scrub cover was left and this had to be dealt with in recent years although by then somewhat overdue.

7. *Thinning*

(*a*) *Acquired woods*. Most of the acquired woods were in the 25–35 year-age class when acquired. The remainder were mature woods beyond the thinning stage. The young woods were mostly planted at close spacing. Light thinnings were the order of the day until recently. In general thinnings, although slightly delayed, have nevertheless been carried out sufficiently early to allow of little harmful effects on the woods.

(*b*) *Commission planted plantations*. Virtually no thinning was done before the end of the war although some stands were ready for thinning. At the end of the war there were extensive areas in the older forests in need of thinning. A systematic start was made to thinning in 1948. Additional labour was recruited and numerous standing sales made to timber merchants in order to catch up the arrears. It has been possible in the last 10 years to bring our thinnings in these forests up to date. Lack of roads hampered thinning immediately after the war but it was surprising what was done even with few or no roads.

Early thinnings were light, but thinnings in the last 6 or 7 years have been much heavier. The C/D grade of thinning was applied in the Douglas fir and spruce plantations and a D grade in the larch plantations. Yields varied from 500 hoppus feet per acre to 800 hoppus feet per acre in the Douglas fir and spruce: about 500 hoppus feet per acre were removed from the larch. It has rarely been possible to return to thin a stand for the second time in 3 years. Generally thinning cycles have been 4 or 5 years but no deterioration in the stands has resulted from that practice. A 5-year cycle seems adequate after the third thinning.

8. *Utilization of thinnings*

Since the end of the war the policy has been to sell standing as large a volume as possible and failing this or where it is necessary for employment of the existing forest squads to sell in the length at roadside. On occasion small sales have been made of poles and sawlogs. Little difficulty has been experienced to date in selling produce either standing or at roadside. The Great Glen is one of the more attractive areas to timber merchants.

Extraction has at times proved difficult on the steep slopes. Considerable quantities have been removed by aluminium, corrugated iron, and wooden chutes whilst the Lasso Cable has been used at Port Clair and Creagnaneun.

The annual yield from thinnings in the Great Glen forests is about half a million hoppus feet.

9. *Lon mor*

Any account of the Great Glen forests would be incomplete without brief mention being made of the experimental work undertaken by the Research Branch on the planting of high-lying peat-covered land of varying types (Fig. 7). The Lon Mor lies within the boundaries of Inchnacardoch forest. These experiments have had and will continue to have

a far reaching effect on soil treatment and choice of species. The history of the area has been written by J. A. B. Macdonald (1945). Briefly the more important aspects of the experimental work which have directly influenced Conservancy planting of difficult areas are turf planting leading to ploughing, manurial treatments, and choice of species.

FORESTS OF THE BASALT SOILS

A. General Description

1. *Forests in group*

In this group there are three forests on the island of Skye, viz. Glenbrittle, Glenvarragill, and Healaval; one on the island of Raasay called Raasay Forest, one on the island of Mull called Salen, and one on the mainland facing Mull called Fiunary. All except Raasay are mainly on basalt soils. Particulars of area are given in Table XI.

Table XI. *Forests of the basalt soils. Land utilization as at September 1957*

Forest	*County*	*Area of acquired plantations (acres)*	*Area planted by Forestry Commission (acres)*	*Area awaiting planting (acres)*	*Unplantable agricultural and other (acres)*	*Total (acres)*
Fiunary	Argyll	72	4,377	1,866	12,023	18,338
Glenbrittle	Inverness	..	1,578	2	7,278	8,858
Glenvarragill	Inverness	..	288	412	7,830	8,530
Healaval	Inverness	26	192	709	338	1,265
Raasay	Inverness	32	497	25	178	732
Salen	Argyll	357	4,387	2,100	17,148	23,992

2. *Land utilization*

Many centuries ago the islands were no doubt covered to a large extent with scrub-birch alder, hazel, and a few oak. In more recent times the land was used for sheep grazing. Small areas were under trees.

3. *Physiography*

Slopes are moderate to steep. At Fiunary, and more particularly at Salen, there are frequent basalt shelves where the rock comes near the surface. Aspects cover all points of the compass. The prevailing wind is from the south-west but most areas face the Atlantic salt-laden winds. Elevations range from sea-level to about 2,000 feet, but exposure is so severe that the upper plantable limit is 700 feet on the more sheltered places and between 200 and 400 feet on the exposed parts of the forests.

4. *Geology and soils*

The three forests in Skye, together with Fiunary and Salen, lie on basalt-plateaux built up of lava streams with intruded olivine-dolerite sills and dykes. The plateau lavas are much eroded into characteristic terracings. Wherever the basalt appears the terraces are level. The dykes and sills, particularly in Skye, are of importance to forestry. Similarly, a relatively small area of cretaceous chalk and sandstone at Fiunary is also of importance. A small part of Glenbrittle forest lies on Lewisian gneiss. The two Forestry Commission areas at Raasay lie on Jurassic oolite and lias and granite.

Soils are derived from the porous quick-weathering basalts and are potentially the richest soils in the west of Scotland. A brown loam is often formed. Peat forms occasionally, particularly on the exposed terraces in Mull. There are also extensive areas of *Scirpus* deep peat at Glenvarragill in Skye and areas of *Molinia* peat on the cretaceous chalk and sandstone at Fiunary. Elsewhere *Molinia* moors are rather uncommon, but there is a tendency for them to increase in the wetter areas.

5. *Vegetation*

The natural vegetation of the basalt areas is hazel which mostly disappeared in the period of sheep farming but remnants can still be found on the Morven shores. Ash also grows naturally. Today as a result of burning and bad grazing the hill ground has eroded and turned to bracken, which covers very extensive areas on *Festuca-Agrostis* slopes on Skye, Morven, and Mull. On the bottom of the valleys sedges and *Erica tetralix* predominate. *Scirpus* is common on areas of poor peat occasionally mixed with *Calluna*, but *Calluna* is not too common on the basalts. Luxuriant *Molinia* is found on the chalk and sandstone area at Fiunary and is not uncommon on the basalt areas of Glenbrittle. At Raasay bracken-birch is the normal vegetation on the better areas while *Calluna* predominates on the higher more exposed slopes. It is believed that Raasay escaped glaciation and rare plants are to be found on the oolite and lias slopes.

6. *Climate*

Exposure is by far the most critical factor to tree growth on the basalt areas. Practically all forest areas are fully exposed to the Atlantic. Only the bottoms of the valleys are sheltered but are still not entirely free from the salt-laden winds. The forest areas are subject to many gales from the north-west, west, and south-west.

Rainfall is heavy ranging from 60 inches on the coastal regions of Mull to 90 inches on Glenbrittle at the foot of the Cuillins. Rainfall is so heavy that there is a serious loss of the finer particles and of the soluble plant nutrients from the soil.

B. Silviculture and Management

1. *Ground preparation*

The quality of the ground on the basalt areas is often such that any forester would expect trees to grow with the minimum of ground preparation. Although a fair measure of success was achieved in the earlier plantings, success was by no means universal and it was not until a few years after the war that slow establishment and growth on what appeared to be very excellent quality ground at Fiunary led Commission foresters to think that there was something wrong with the soil and in this belief ploughing was started in Fiunary in 1949 and in Mull in 1951 (Figs. 10 and 11). Results from the ploughing were startling. Apart from the fact that uniform growth was achieved, the growth was so good that after 6 years on ploughed ground the height of the crop equalled the height of crops 20 years old on unploughed ground. It has now become standard practice to plough as much as possible, whether the soil quality be good or bad. Apart from growth initial establishment is considerably improved by ploughing probably due to the fact that the ploughing helps to conserve such early spring moisture as there is in the soil. Ploughing is mostly done by Begg plough.

2. *Choice of species*

One of the main species planted in the early days was Norway spruce which was used wherever there was a predominance of grass. Norway spruce by the early 1930's had given

way to Sitka spruce and Japanese larch, the latter being planted on the drier slopes covered by grasses, sometimes in admixture with heather, and the former on moister *Molinia*/grasses slopes and flats. Scots pine was also planted on the drier heather slopes but failed largely on account of exposure to the salt-laden winds. Today, apart from sheltered grassy slopes facing away from the sea where Norway spruce is planted, species is limited by and large to Sitka spruce, Japanese larch, *Pinus contorta*, and Corsican pine.

Corsican pine has not been used extensively but its use is increasing on firm heather ground. In the early plantings it was used on drier harder bracken/grass slopes. Japanese larch originally widely used on all good quality soils is now used on dry grass/heather soils which are not too exposed. Sitka spruce is used very extensively nowadays on all deep grass, grass/bracken, and *Molinia* soils. Owing to the very limited range of species which will stand exposure Sitka spruce is not confined to the moister areas but is also used on the dry deep soils. Norway spruce is used on a small scale on the sheltered backward moist grassy slopes. *P. contorta* is used on all the poorer soil classes and on the exposed drier harder soils.

3. *Planting*

Planting started at Salen in 1925, Fiunary in 1931, Glenbrittle in 1932, Raasay in 1950, Glenvarragill in 1955, and Healaval in 1956. Considerable areas were planted pre-war at Salen and Fiunary, whilst since the war progress has been rapid. Today, on the six forests the annual planting programme is about 800 acres. Planting has been completed at Glenbrittle and Raasay.

4. *Success of species planted*

Although there were good stands of Scots pine at Raasay which the Commission acquired, little success has been attained in planting this species. Exposure to salt-laden winds has killed out any areas planted although plants reared from seed of west coast origin might have met with better success. Certainly trials laid down in the last 3 years appear to have better prospects. The origins used are Achnashellach and Raasay.

Corsican pine has grown slowly but the few early stands P 26 and 27 in Mull and P 35 and 36 at Glenbrittle do not appear to be entirely at home on rich bracken ground.

P. contorta was not used very extensively until recent times. In the early days land qualities accepted for planting were good and only isolated pockets were planted with *P. contorta* but in general the origin of the *P. contorta* was wrong for the exposed basalt areas. *P. contorta* is used fairly extensively now on the poor *Scirpus* peats and on good exposed harder ground where it is the one species apart from Sitka spruce which will stand exposure moderately well. Growth in the plantings of the last 10 years has been satisfactory.

European larch in the young plantations has been most unsatisfactory. Where it has survived it is very rough, cankered, and has a most unhappy appearance, although it is true that it was often planted in too damp soils.

Japanese larch, except on exposed areas, has put on good height growth and is a heavy volume producer but frequently owing to the good quality of the soil it tends to be very crooked. Sitka spruce would today be used on many of the areas carrying a Japanese larch crop. On exposed sites it was for a time after the war used as a nurse for Sitka spruce. While in this respect it served its purpose, it developed on exposed areas after 6 or 8 years into a bush and had to be cut back or removed to prevent damage to the spruce. Nevertheless, Japanese larch is a valuable tree for the basalt areas and a heavy volume producer, but it is of low utilization value.

Douglas fir has not been used and Norway spruce has grown satisfactorily on sheltered

spots on all forests. The early plantings of Norway spruce on good exposed sites failed completely and the Norway spruce has given way to Sitka spruce. Only small quantities of Norway spruce are planted today.

The main species planted on the basalts and by far the most successful species is Sitka spruce, although some of the most successful areas are where the geological formation is not true basalt, as for example the cretaceous chalk and sandstone area at Fiunary and the area of outcropping sills and dykes at Glenbrittle. Growth has often been slow, in fact on the pre-war unploughed land it was practically always slow until the first thinning stage was reached. Up to 20 to 25 years of age the trees are short and quick tapering but thereafter with a height increment of about 2 feet per annum they quickly assume more normal shape. On ploughing, fast growth from the start is a feature. Sitka spruce has been used and more so today is used wherever possible on dry and moist soils. In the older plantations it is now becoming apparent that on the convex slopes as opposed to the concave slopes, although the increment is normal, the crowns of the trees are very thin and of a somewhat unhealthy appearance probably due to spring drought. There are areas of Sitka spruce which although not entirely in check have grown extremely slowly sometimes on a heather/grass vegetation but more commonly on grass covered areas. Partly it is believed that shortage of moisture is to blame and partly the fact that nutrients are bound up in an insoluble state in the soil.

5. *Beating up*

There are always a considerable number of deaths on the porous basalt areas and these are not confined to any particular species although the larches and pines suffer more than the spruces. In the light of experience there have been frequent changes of species moving towards a greater proportion of Sitka spruce and the substitution of *P. contorta* for Japanese larch on the more exposed sites.

6. *Weeding*

Areas to be weeded are often vast because of the quantity of bracken which is present. There have been instances when for a time the planting programme has had to be reduced because of the insufficiency of labour to deal with the areas to be weeded. Often two weedings per year are necessary and areas require to be weeded for up to 4 years after planting. Weeding has been made easier on areas where ploughing has been carried out.

7. *Thinning*

Marketing difficulties have had an unfortunate effect on thinning. In most cases thinning has been delayed at one time or another and when thinning has taken place it has been fairly heavy and at rather irregular intervals. The thinning grade has largely depended on the availability of a timber merchant to take up the resultant produce.

Thinning in Skye has not been of very significant dimensions and has been carried out at 3-yearly intervals, and in this instance thinning was started in time. Only one thinning has been carried out in Mull correctly when due but this was 5 or 6 years ago and a second thinning is overdue. On Fiunary up to three thinnings have been carried out on certain areas of Sitka spruce. First thinning yields were relatively light—300–400 hoppus feet per acre but heavy yields can be obtained in second and subsequent thinnings, ranging up to 1,000 hoppus feet per acre.

8. *Utilization*

In Skye and at Fiunary the thinnings were sold in the length at roadside. In Mull the thinnings were sold standing on a 5-year contract at about 30,000 hoppus feet per annum.

The thinnings were all converted into pit props and sawn mining timber by timber merchants. Due to geographical difficulties prices obtained have been low.

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We wish to acknowledge the generous assistance and criticism given by Mr. James Fraser, late Conservator of the North Scotland Conservancy. We also acknowledge the help given by our Conservancy and Research Branch colleagues.

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JAMES FRASER

When he returned the proofs of his paper 'Forestry in North Scotland', Mr. Dickson told us of Mr. James Fraser's sudden death in Inverness on 31 January. Mr. Dickson says, 'Although I could not persuade him to write this article, he spent a lot of time reading, correcting and criticising it and most of his suggested amendments were incorporated in the final draft.'

A friend who had called on him at his home earlier in the month, records his great qualities and adds, 'He was one of the outstanding characters of British forestry and will be much missed and long vividly remembered by all who knew him.'

A fuller appreciation will appear later.

REVIEWS

Foresters' Engineering Handbook. By E. R. Huggard. W. Heffer & Sons Ltd. Cambridge, 1958. Pp. 149. Illustrated. Price 18*s*. net.

Review by G. B. RYLE

THE last decade has seen the publication of many—perhaps too many—textbooks for the edification of forestry students, foresters, and forest owners, but forest engineering has remained one of the black arts. Huggard, despite the title of his book, addresses himself promiscuously to the forester, forest officer, forestry officer, forest engineer (yes, he does accept that name), and lastly to the silviculturist. The silviculturist is a man lamentably placed in charge of forests but he has no interest in any aspects of his work other than the growing and admiration of his trees: to him the engineer and all his machinations are almost indecent. Let us admit that such men do exist both amongst professional grades and amongst woodland owners, but they are a dying race and they will not read this book anyhow. Foresters need not be tarred with the same brush even if they do embrace a knowledge of silviculture amongst their other skills. If engineering has not hitherto been one of their strongest subjects the fault is not theirs and Huggard has now made a very real effort to help them over the stile.

Roads and bridges are the keystone of forest engineering and here, in a book of 146 pages of text, well over half, and by far the best half, has been devoted to this subject and to the tackle required for road and bridge construction. In fact there is so much sound information on roadwork that I think it is a pity that some aspects have been all too lightly skimmed over in order to make room at the end for two rather disjointed chapters on mapping, surveying, and aerial photography. The student engineer has access to plenty of textbooks on these matters and Huggard could so much better have used the space for his real subject of forest engineering.

A few years of intimacy with foresters (or is it silviculturists?) seems to have convinced the author that parsimony is more important than economy and he therefore accepts, though sadly and apologetically, that second-best must often be good enough where forest engineering is concerned. This is not a happy attitude: we would rather see a true economy being attained by sound planning and solid construction allied to a really keen cost control as the works proceed. We are not told much about cost control or site management. Discussing the use of the face shovel we are told 'it seldom *happens* that sufficient lorries are available to balance loading capacity with carrying capacity'. This calls for better site management or a reprimand to the silviculturist.

How many roads do we need in our forests? Having been shown how to make the calculation we find that some of the basic factors remain unknown and so we come back to the old formula of 8 miles per square mile which is probably pretty sound. Nevertheless it is actuarially incorrect to work the calculations solely on the basis of a single crop rotation. On the timing of road construction we are given some over-simplified advice. Obviously if the roads are needed *only* for exploitation of a crop the expenditure on their construction should be postponed till the last possible moment before felling. The economics of the forest are not, however, solely dependent upon exploitation. Protection should have been given proper and serious thought in relation to various degrees of fire risk and fire hazard: then it could not be postulated that 'it is extremely uneconomical to construct roads during the first 5 years of a plantation'. In much of Britain's white moorland especially, the fire

danger is highest in the 2nd to the 10th years after cultivation and afforestation: the economical time to make roads thus might well be in the 1st and 2nd years after planting. The principles of stage construction, vital for sound economy in this respect, might have been given more detailed consideration. Stage construction is not 'a matter of trial and error', it is a process of spreading the capital cost of the road as required for the management of the forest, starting, maybe, with the very light needs of a fire trace and access and finishing with the full load carrying logging road 20 years later. Still on the ignored subject of fire protection it is a pity that the matter of fire dams in conjunction with the road drainage system has been dismissed in two lines. Adequate fire dams should be an invariable adjunct to forest roads wherever there is a trickle of water to be conserved.

Water control, especially as an absolutely vital part of sound forest road construction, is mentioned here and there but it really should have been dealt with in more detail and with greater stress. It is puzzling to be told that intercepting drains excavated on a hill slope above a contour road 'are the exception rather than the rule'. Having dealt with the unwanted water on and above the road formation we are given very little useful guidance as to its subsequent disposal below or as to elimination of under-cutting troubles at the outfall of culverts. Perhaps that is a silvicultural not an engineering headache. To fill over a bog with soil or gravel is a sound way of crossing it with a forest road, but we learn that for a civil engineer to do such a thing is to commit professional suicide. We have heard accounts of this practice being adopted by reputable civil engineers for many centuries. Does not the main line railway across Tregaron Bog lie on countless sacks of wool? But again, please drain the bog as efficiently as possible beforehand and then keep the water flowing away.

In making a new road through an established forest the silviculturist tends to be over canny about the width of the crop he is prepared to sacrifice. Then he and the engineer start tearing each other's hair. Perhaps the wise solution is to make a minimum clearance first, thereby setting a barrier to control the slap-happy bulldozer driver and the turbulent rock blaster. Then when the formation has been completed a wider opening-up will enable the road to be finished and kept clear of dankness.

Before advancing to bridge construction we are treated to a very brief dissertation on concrete work. Reinforced concrete work, however, is virtually dismissed as 'it is unlikely that a forest officer will be called upon to carry out any work in reinforced concrete excepting, maybe, posts and a few other small items'. One would think that posts at any rate would seldom appeal to the forest officer as items to be made in concrete! Even though valuable information is provided on the strength and construction of timber and steel bridges it is hardly conceivable that a forest officer will not occasionally have recourse to reinforced concrete structures also. Suspension bridges, which are accepted as being suitable for light traffic only, are given more space than girder bridges. We are told about span and dip, but we can find no guidance as to the suitable distance between the anchors and the piers nor as to how the main cables are evenly tensioned and fixed at the anchors, nor how they should slip over the pier caps.

As a professional engineer and an Irishman it is good to find that Huggard has quite pleasant views on the horse as a means of timber extraction on a short haul, but he foresees the early extinction of the species and the need to change over to machinery. Our silviculturist might care to take up the challenge and encourage the breeding of suitable horses because there is no doubt that they are far more versatile in broken country than anything on wheels or tracks. The use of aerial ropeways is, probably correctly, considered to be of small economic importance. If I were to erect a ropeway I should want to know something more than that 'three anchor bars fully picketed' would be adequate to support the fully tensioned cable. With this exception the ropeway problems are admirably discussed.

There are a few errors: the passing place in the plan on page 10 should obviously be 20 feet, not 60 feet wide: a main final thinning on page 2 is presumably a final felling: the depth of the hollow in the detonator, not in the fuse, should be tested by the proposed method on page 81: it is the bubble tube not the bubble itself which has graduations on page 130: it is the focal length, not the focal lens which governs the area covered on the plate on page 137.

The book, except for the last chapter, is numerically paragraphed and well cross-referenced and the index appears to be good. There are numerous useful tables and methods of calculation scattered throughout the text, while the diagrams, sketches, and silhouettes are admirably clear and simple. Several well-selected photographic plates go to complete a book which has cracked, if not entirely broken, some very new ice in British forest literature. It is clear, in my mind, that the forest officer must have full personal responsibility for his road planning in location and in timing. He must also have direct responsibility for organization of the works, but he should not be slow to secure the services of an engineer either as his consultant or as his agent. In fact if he fails to do so and the works or the costings suffer thereby, the blame will be entirely his. On the other hand the forest officer should be sufficient of an engineer himself to know when or when not to require these specialist services: he should expect and be encouraged to use his own judgement more and more as he gains experience. This Forester's Engineering Handbook will help him a lot.

Forest Machinery. By E. R. Huggard and T. H. Owen. A. & C. Black, London, 1959. Pp. xii and 192 with 123 illustrations, 8½ inches by 5½ inches. Price 24*s*. net.

Review by G. D. Rouse

At a time when the cost of forest labour is still tending to increase whilst the price for forest produce, particularly pit props and oak timber, is falling, it is essential to consider every means of reducing operating costs. One method is by increased and efficient use of machinery and the authors are to be congratulated on bringing out this book at such an opportune time.

It is perhaps a reflection on the lack of specialized cultural implements that all cultural operations are disposed of in 40 pages, but the impression is obtained that the authors are more interested in road construction which occupies the next 45 pages, in which the bulldozer is described, almost lovingly, (twice) as 'the King of the forest road plant'. The remaining 78 pages cover saws, winches, extraction, forest protection and ancillary equipment. Throughout the book and occupying about half the total space are 123 illustrations. The authors acknowledge their indebtedness for these to the manufacturing firms and give the name of the maker against each photograph.

They also give full names and addresses of all the firms concerned. This will undoubtedly be useful to a proportion of readers, but others may consider that, at 24*s*., they are paying dearly for information much of which would be freely available at any major agricultural show or from contractors. Although the illustrations appear on pages with appropriate subject-matter, they are not closely linked with the text, and, in a book dealing specifically with forest machinery, a little more trouble might have been taken to illustrate the machines performing forest operations. (A steerage hoe is shown working between rows with a spacing more appropriate to sugar beet than to forest tree seeds.)

The authors are both lecturers at the University College of North Wales and the book will form a valuable introduction to the subject for students. It may also provide a stimulating challenge to the inventor or enterprising manufacturer by high-lighting those fields which are not yet adequately served by suitable machinery.